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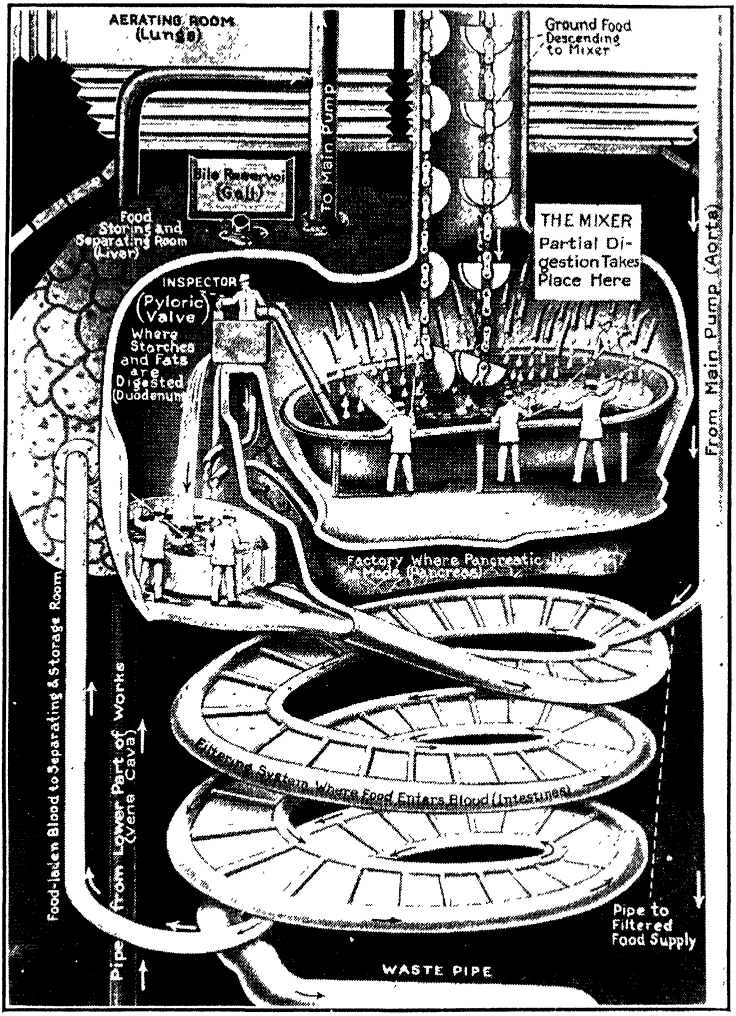

From Compton's "Pictured Encyclopedia" F. E. Compton & Co.

OUR FOOD FACTORY

This is a diagrammatic picture of the organs of digestion. The food comes down from the mouth to the stomach where it is thoroughly mixed and where part of the proteins are digested by fluids from the stomach walls. When properly mixed with this gastric fluid the food passes the inspector and enters the intestine where fluids from the liver and pancreas complete the process of digestion. As the digested food passes along the small intestine the useful parts are absorbed into the blood. The process is more fully described in Chapter XL.

BIOLOGY FOR BEGINNERS

REVISED EDITION

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PREFACE

A textbook for beginners must make clear-cut statements and sharp distinctions. Nature seldom provides such exact boundaries; for there is hardly a generalization which is not subject to some exceptions if one looks for them. If every statement in an elementary book is modified by exceptions, a beginner gets a vague idea or none at all.

For example, we tell a beginner that all living things need air. This is a useful generalization; but a bacteriologist would cite exceptions in the anaërobic bacteria. We say that carbon is an insoluble element. And so it is, so far as biology is concerned; but the chemist objects that Moissan dissolved it in iron in the electric furnace.

Similar cases arise in the experience of any teacher of young pupils. Shall we go into detail, state all conditions and exceptions, and confuse the beginner, or shall we state broad general truths and leave the exceptions till later? The author's experience favors the latter plan and he follows it in this book. He does not aim to sacrifice accuracy for simplicity, but he does try to avoid encumbering details when teaching a beginner.

Just as content is of first importance in teaching beginners, so are organization and teaching equipment of vital concern. The course here presented emphasizes the fact that biology is a unit science, based on the fundamental idea of development, rather than a forced combination of portions of botany, zoölogy, and hygiene. Within each chapter the arrangement is such that it is easy for the pupil to study, outline, and remember each lesson.

Outlines, tabulations, diagrams, and vocabularies take up a larger proportion of pages than in any similar text. The numerous diagrammatic line drawings are intended to simplify matters of structure for the beginner who would have difficulty in selecting the essential points of a photograph or highly detailed line drawing. It is hoped also that a reasonable use of line

drawings will help the pupil in his laboratory work by affording models which he can easily approximate.

To facilitate collateral reading, extensive lists of exact page references have been added to each chapter. Most of these have been used by the author and his pupils and are of known value. It is not supposed that every school will have all the books to which reference has been made; but from so large a list, many references on each chapter will surely be available.

No laboratory work is included in the text. Such a plan tends to invite copying from the book rather than gaining the information from observation of the material in hand. In a separate manual such as the author has prepared more complete directions can be given and more detailed results required.

ACKNOWLEDGMENTS

In offering to the public this Revised Edition the author desires to acknowledge the many helpful suggestions received from various sources. A large number of these have been based upon actual teaching experience with the text.

The scientific accuracy and artistic execution of the line drawings are due to the skilled hand of Miss Ellen Edmonson of Cornell University.

Mr. Paul B. Mann, Head of the Department of Biology in Evander Childs High School, New York City, and Dr. John H. Gerould, chairman of the Department of Biology at Dartmouth College, have assisted with valuable suggestions as to subject matter. Constructive criticism of high order has been contributed by Professor L. L. Woodruff, of Yale University.

The author is especially indebted to the cheerful assistance of his wife in the laborious task of reading and correcting the proof, and to his fellow teacher, Miss Catherine E. Reed, for many helpful suggestions as to content and arrangement.

If there be aught in the Revised Edition to make it of greater value to teacher and pupil let it be to the credit of the authorities consulted and help received; for its many shortcomings the author alone is responsible. T. J. M.

March, 1926.

CONTENTS

CHAPTER		PAGE
I.	Introduction	3
II.	The Likeness of Living Things	7
III.	Elements, the Alphabet of Living Things	11
IV.	Compounds, Biology's Building Materials	20
V.	Protoplasm, the "Bios" of Biology	31
VI.	The Structure of Seeds	40
VII.	Germination: The Seed Wakes Up	49
VIII.	Roots: Their Structure and Function	57
IX.	Absorption and Osmosis	65
X.	Stems: Their Forms and Functions	76
XI.	Stem Structure	84
XII.	Leaves and Leaf Structure	96
XIII.	Leaf Functions	106
XIV.	Flowers: Pollination and Fertilization	117
XV.	Fruits and Their Uses	127
XVI.	Spore-Bearing Plants	135
XVII.	Bacteria	142
XVIII.	Protozoa	159
XIX.	Metazoa	167
XX.	Worms	174
XXI.	Arthropods	182
XXII.	Crustacea, a Class of Arthropods	188
XXIII.	Insecta, a Class of Arthropods	199
XXIV.	Insecta (*continued*)	212
XXV.	Insects and Disease	231
XXVI.	Introduction to the Vertebrates	246
XXVII.	Fishes	251
XXVIII.	The Frog and Its Relatives	266
XXIX.	The Amphibia: Life History and Habits	281
XXX.	Reptiles	289
XXXI.	Birds: Their Structure and Adaptations	303

CHAPTER		PAGE
XXXII.	Bird Habits	316
XXXIII.	Bird Value and Protection	330
XXXIV.	Mammals	345
XXXV.	The Development of Man	359
XXXVI.	The Method of Evolution	364
XXXVII.	The Development of Civilized Man	370
XXXVIII.	The General Structure of the Human Body	377
XXXIX.	Food	389
XL.	Nutrition	409
XLI.	Respiration	431
XLII.	Circulation	443
XLIII.	Excretion	457
XLIV.	The Nervous System	462
XLV.	The Sense Organs	477
XLVI.	Biology and Health	487
XLVII.	Civic Biology	501
XLVIII.	The Economic Biology of Plants	508
XLIV.	The Economic Biology of Invertebrates	541
L.	The Economic Biology of Vertebrates	541
LI.	Biology and Agriculture	547
LII.	The Economic Importance of Forests	557
LIII.	Conservation of Natural Resources	569
LIV.	Tobacco and Table Beverages	591
LV.	Alcohol in Relation to Biology	596
LVI.	Some General Biologic Processes	608
LVII.	The Historical Development of Biology	621
	Appendix	635
	Index	i

BIOLOGY FOR BEGINNERS

CHAPTER I

INTRODUCTION

The student should make sure that he understands every term used in his Biology lessons. This book will include vocabularies like the following, but in addition, a good dictionary should be consulted frequently and derivations studied. As is shown in the first paragraph on this page, a great deal can be learned about the meanings of scientific terms by looking up their derivations.

Vocabulary

Domestic, tamed, as applied to animals and plants used by man.
Biology, the science of living things.
Organic, pertaining to living things.
Inorganic, pertaining to things which have never been alive.

Biology is the study of living things. The dictionary tells us that this term comes from two Greek words, "bios" which means "life" or "living things" and "logos" from which we get the word-ending "ology," meaning "the science or study of." Thus the two parts make a perfect definition of biology, "the science of living things."

Classes of Things. All things in the world can be divided into two classes; those which are, or have been alive, and those which have never lived. The former are *organic* substances, and the latter *inorganic.*

Organic things include both plants and animals, together with all substances derived from them. Inorganic things include the members of the mineral kingdom such as stone, glass, or iron, as well as water, carbon dioxide, oxygen, and similar substances. Biology is the science which deals with the study of organic things, as its derivation shows.

Words as Tools. Since three new words have been used already—biology, organic, and inorganic—it may appear that the subject is to be made difficult because of many hard and strange terms. There need be no alarm at the prospect if we

will consider each new word as a tool which will enable us to do our work better, more accurately, and more easily.

It is simpler to say "organic substances" than to say, "substances which are or have been alive." It is also more accurate, and furthermore we have increased our vocabulary by the addition of this new tool.

We should think a carpenter very foolish who cut all his lumber with a jack knife because he thought it too much trouble to learn to use a saw. Students in their school life are workmen, and their most important tools are *words*. Each subject taken up, like different kinds of carpenter work, requires the use of a certain number of new tools (words). These must be learned before the student can do his work efficiently.

On the other hand a carpenter would be foolish to load up his chest with a lot of tools which he rarely used. In our study, we have included only those new names and terms without which we could not possibly get along. If we learn to use them, we will not have to "cut off our board with a jack knife."

Sciences Included in Biology. Although biology is a single and closely united science based on the study of all things that are or have been alive, it is so broad in scope that it includes many special branches. Some of these are already familiar, such as botany, which deals with plants; zoölogy, which deals with animals; hygiene, which concerns the care of the human body; physiology, which is the science of the use or function of living organs; and many others.

Familiar Biology. To begin with, each one of us has studied biology already by observing the things of nature about us. Is this not true? We know some plants and trees by name. We know how to cultivate gardens, what will help plants grow, the names of many flowers. All of us buy and use fruits, grain, and vegetables. We also know something about the care of animals, and, most important of all, are anxious to learn all that we can about the care and use of our own bodies.

Reasons for the Study of Biology. Biology is a required study in many schools, and we have a right to ask why it is considered so important that we are obliged to study it.

In the first place there are few subjects that add so much to general culture by increasing the number of things in which we are interested and about which we should have information.

Few people really *see* very much in the things about them—accurate observation is a very rare but valuable trait, and the study of biology will greatly increase the powers of observation.

Mere observation of facts is not enough, however, for one should be able to draw correct conclusions from what he sees. This ability to think and reason is one of the chief aims of the laboratory work in biology or any other science.

Although these reasons for the study of biology are by far the most important, others can be mentioned which may seem more practical. It is the foundation of farming, gardening, and forestry and upon its laws are based the care and breeding of all domestic animals and plants.

In even a more personal way, biology deals with the health and care of our own bodies—*hygiene*. It also includes the study of the cause and prevention of disease, the work of bacteria, and means of maintaining healthful surroundings—*sanitation*.

One-half of all human deaths are caused by germ diseases and at least half of these could be prevented by proper knowledge and practice of *hygiene* and *sanitation*. This in itself is sufficient reason for interest in the study of biology.

SUMMARY OF CHAPTER I

INTRODUCTION

1. Biology.
- a. Derivation of the word.
- b. Definition.
- c. Sciences included.
- d. Familiar biology.
- e. Reasons for study.
  - (1) Adds to culture.
  - (2) Cultivates power of observation.
  - (3) Teaches to think and reason.
  - (4) Important in industries.
  - (5) Related to health control.
    - (a) Hygiene.
    - (b) Sanitation.

2. Classes of things.

a. Inorganic.
   (1) Definition.
   (2) Examples.

b. Organic.
   (1) Definition.
   (2) Examples.

3. Words as tools.

CHAPTER II

THE LIKENESS OF ALL LIVING THINGS

Vocabulary

Assimilation, "to make like," that is, the process by which food stuff is made into tissue.
Nutrition, all the processes by which food is prepared and assimilated in the body.
Respiration, the process of breathing.
Reproduction, the process by which an animal or plant gives rise to another of its kind.
Excretion, the passing off of waste matter from plant or animal.
Sensitivity, power of reacting to outside forces.

Biology, then, is the study of all living things, and living things include both plants and animals. At first one would say that plants and animals have very little in common. A buttercup and a butterfly, for instance, seem so different that it may appear difficult to study them together. Actually they are alike in more important ways than those in which they differ, as our further study will show. In fact there are some living things of such uncertain character that it is difficult to tell whether they are plants or animals.

Not only are plants and animals similar, but they depend upon each other in many ways, so that one group can hardly be studied without the other. That many animals depend on plants for food, and that many plants require help from insects in pollination, are facts already well known to us.

Man, like other animals, is dependent on plants for many things and on animals for many more; plant life and animal life touch each other at many points. Their life processes are alike in many ways. This is what makes biology a single, closely related subject. When so studied, it is both easy and interesting. Let us see some of the ways in which plants and animals resemble each other.

Nutrition. First, both plants and animals are alive and grow in size. That means that they *both need food.* A cat, for instance, has to eat and drink, and a geranium has to have earth, water, and air in order to live. The cat obtains its food by means of its claws and teeth, while the food-getting of the plant is done chiefly by the roots and leaves. They are both dependent on food.

After they get their food, both plants and animals have to put it into liquid form in their bodies. We call that process *digestion.* Then the digested food undergoes a change by which the milk or meat actually becomes part of the cat, while the plant foods become part of the geranium. This is a very wonderful process and is called *assimilation.* (Look up this word in the dictionary and see if you can tell why it is used in this way.)

Food-getting, digestion, and assimilation together make up the process of *nutrition* (getting nourishment). The animal and the plant have this process in common.

Circulation. Most animals and plants have some sort of fluid like blood or sap, which flows through their bodies carrying digested foods, oxygen, and waste matters, although some living things are so small and simple in structure that they do not need a circulatory system. The protoplasm sometimes flows or "circulates" *within the cells,* though this is not circulation in the usual sense.

Respiration. Another point in which the cat and the geranium are alike is that they both breathe. If we keep either one in an air-tight box it will die. The cat breathes by means of its lungs and it is easy to see the muscular movements involved. The leaves of the plant breathe too, although our eyes cannot detect the way in which this is done. The process of breathing is called *respiration* in both cases.

Excretion. Both cat and geranium use the food that they assimilate to build up their bodies or to give them energy, and both throw off from their bodies unused and changed materials by a process called *excretion.* The animal does this by means of the lungs, skin, intestines, and kidneys; the plant chiefly by means of the leaves.

Motion. Another way in which all living things are alike is in the power of *motion*. It is easy to see the cat move, but few observe how the geranium turns its leaves to the light and its roots to the water. Though animals usually have greater freedom of motion, plants do not lack it altogether.

Sensitivity. In a general way, all plants and animals have the power of responding to touch, heat, light, and other forces outside of themselves. This is *sensitivity*, and may vary in its expression, from the mere turning of leaves toward light to the delicate operation of a wonderful sense organ like the human eye.

Reproduction. Both plants and animals *reproduce* others like themselves. Kittens are born and grow to be cats, and the plant bears seeds which will produce other plants like itself. By this wonderful provision of nature, although all organic things die, others like them are left to take their places. The processes of reproduction and nutrition are the two most important characteristics of all living things.

Likeness of all Living (Organic) Things. The cat before the fire and the geranium on the window sill, though apparently different, are really alike in all of the necessary processes of life. It is, therefore, possible and easy to study plants and animals together. Biology is not merely botany plus zoölogy, but a study of the life processes of all living things.

Difference from Inorganic Things. The points in which all living or organic things are alike are also the points in which they differ from inorganic things. A stone and a piece of iron are familiar examples of inorganic matter. We cannot imagine a stone taking food or growing, or a piece of iron moving or reproducing its kind.

To be sure, plants can take inorganic matter and by certain wonderful processes make it into the living plant as we have mentioned. But it then ceases to be inorganic and becomes a part of the plant. Plant and animal are alike in all essential ways and they also differ in these ways from all inorganic substances.

Processes in which Organic Things are Alike

Process	In plants is performed by	In animals is performed by
Food-getting	Roots, leaves	Teeth, claws, etc.
Digestion	Ferments in the tissues	Stomach, intestines, glands, etc.
Absorption	All live tissues	Intestine, stomach, etc.
Assimilation	" " "	All live tissues
Respiration (oxidation)	Air spaces and tissues	Lungs, gills, etc., all tissues
* Circulation	Ducts, bast tubes	Heart, blood vessels
Excretion	Leaves	Kidneys, skin, etc.
Motion	Flowers, leaves, tendrils, etc.	Legs, wings, fins, etc.
Sensitivity	Leaves, tendrils	Nerves, sense organs
Reproduction	Seeds, slips, etc.	Eggs, live young

* Circulatory organs not found in simple forms.

What evidences can you give of any of these processes in either plants or animals?

Since both plants and animals perform similar processes, what might you expect about the stuff they are made of?

COLLATERAL READING

General Biology, Sedgwick and Wilson, pp. 1–19; *Applied Biology,* Bigelow, pp. 10–22, 122–132; *Elementary Zoölogy,* Galloway, pp. 36–54, 72–97; *Biology,* Calkins, pp. 6–15; *General Zoölogy,* Pearse, pp. 25–36.

SUMMARY OF CHAPTER II

LIKENESS OF LIVING THINGS

Organic things (plant and animal)

1. Processes performed by organic which cannot be performed by inorganic things.
   a. Live, grow, and usually move.
   b. Obtain food.
   c. Digest and absorb food.
   d. Assimilate food as part of themselves.
   e. Excrete waste.
   f. Reproduce.

CHAPTER III

ELEMENTS, THE ALPHABET OF ALL LIVING THINGS

Vocabulary

Elements, a form of matter that cannot be further simplified by any known means.
Compound, a substance formed by the union of two or more elements.
Oxidation, the union of any thing with oxygen.
Combustion, rapid oxidation, producing light and heat.
Insoluble, not capable of being dissolved, as in a liquid.

All the words of our language are made from less than thirty letters. If we think of our big dictionaries we realize what an enormous number of different combinations can be formed from a few letters.

Elements and Compounds. In something the same way, all the matter in the world is composed of about eighty substances called *elements*. These we might think of as the letters in a chemical alphabet which spell all the substances—both organic and inorganic—that are in existence. When elements unite, they form all the innumerable things that compose the world around us. These substances, formed by the union of two or more elements, are called *compounds*. For example, iron is an element. Oxygen in the air is also an element. When these two unite, they form a compound which we call iron rust.

Living things are chiefly composed of ten or fifteen elements, but when we stop to think of the thousands of kinds of plants and of animals, and of all the different substances of which they are made, we see that these few elements are enough to make a wide variety of compounds.

What to Learn about Them. The complete study of elements and their compounds is called chemistry, but for the

present we need to learn only four things about the elements which compose organic substances: (1) their names, (2) where they are found, (3) enough of their characteristics or properties so that we can recognize them, and (4) their use to living things.

Oxygen

Where it is Found. We already know that oxygen (O) is part of the air, but it is also a part of water, sand, soil, rock, and many other things. It may be hard to understand how a gas, like oxygen, can be a part of a liquid, like water, or of a solid, like wood, but this is true. Oxygen is found in all plant and animal substance. In fact it is the most abundant element in the world, and is itself one-half of the solid material of the earth.

Properties. We shall see oxygen prepared in the laboratory, and shall discover that it is a colorless, odorless, and tasteless gas. It is heavier than air, will dissolve slightly in water, and most curious of all, though it will not burn, it nevertheless makes other things burn very rapidly. Iron, copper, and many other substances which do not seem to burn at all in the air will do so in oxygen, while sulphur and wood, which do burn in air, burn very fast in oxygen.

Test. It is the only substance which will cause a glowing splinter to burst into flame. This fact is utilized in testing whether a gas is oxygen or not, and is therefore called a *test* for oxygen.

Oxidation. When anything unites with oxygen, the process is called *oxidation,* and the compound formed by the substance and the oxygen is called an *oxide.*

Oxygen may unite with substances rapidly, as when a stick burns, or slowly, as when iron rusts. An oxide is always the product, and there is always another important product, namely, *heat energy.*

Life. It is hard to say just what life is, but it seems to require oxidation if it is to continue, hence when oxidation takes place *in living things,* not only is heat produced, but life itself seems to depend upon the process. This life force which ac-

companies oxidation is sometimes called "vital energy" to distinguish it from heat or other kinds of energy. The name is not satisfactory for we really do not know what "life" is. Oxidation appears to be necessary if life is to go on, but life is surely more than oxidation and we have to recognize a Creator as the original source of that which keeps all organic things alive, whatever name we give to the energy involved.

Both plants and animals use oxygen. All plants and animals therefore depend on oxygen which they take into their bodies by breathing, as we have seen in Chapter II. As the living tissues become oxidized they produce heat and vital energy, leaving a residue of oxides and other material to be thrown off as waste. The food assimilated as tissue contains energy which oxidation or some other chemical process, releases.

Live and Dead Engines. A living organism is often compared to a steam engine. Both need a supply of food (fuel), and both must have oxygen to unite with (oxidize) the food and set free its energy. In both, heat is produced by this oxidation and then changed into motion, and in both there are waste products which have to be removed.

But an engine is only an inorganic thing. It cannot get its own food, it does not assimilate or grow, it does not excrete its waste products, or reproduce. Really the only way in which it resembles a living thing is that it depends on energy which is released from substances by uniting with oxygen, and turns this energy into motion.

RESEMBLANCES

	A living organism	A steam engine
Requires	Food	Fuel
To unite with	Oxygen	Oxygen
By means of	Respiration	Draft
To produce	Heat and "vital" energy	Heat and mechanical energy
Leaving	Unused food	Ashes
Waste	Carbon dioxide (in breath) water, etc.	Carbon dioxide (in chimney gas) water, etc.

DIFFERENCES

A living organism	A steam engine
Is alive	Is not alive
Grows in size	Does not grow
Repairs wear	Wears out
Reproduces	Cannot reproduce

Similarities are based on oxidation; differences, on functions of the protoplasm.

Other Uses of Oxygen. Oxygen has many other uses in nature. It causes combustion from which we get heat and power. It also causes rusting, oxidation, and aids in decay. Its numerous compounds are absolutely necessary as food and drink. But its chief importance in biology is that, by uniting with the substance of both plants and animals, it sets free the energy which keeps them alive. Without oxygen, no life can exist, except in the case of certain bacteria.

Harmful Oxidation. Oxidation may also cause harm. Fire is a tremendously destructive agency, and of course it is merely rapid oxidation which has gone beyond control. Rusting of metals is also oxidation, and causes enormous loss every year in the destruction of all sorts of exposed metal work. Some forms of decay which harm food stuffs and other useful substances are in part oxidation processes.

NITROGEN

Where it is Found. Nitrogen (N) is another important element. It makes up four-fifths of the air. It is found combined with several minerals in the soil and exists in the living tissue of all organic things.

Properties. Nitrogen is a gas which resembles oxygen in being colorless, odorless, and tasteless, and in that it will not burn. It is less soluble in water and lighter in weight. It is the exact opposite of oxygen in its behavior, for it will not cause combustion, nor will it combine readily with other elements. Its compounds decompose easily.

Uses. It is found in the active living substance of all plants and animals and is essential to their life. Its various compounds are among our most necessary foods.

Many fertilizers which we use for plants, as well as meat, milk, eggs, and many other animal foods contain very important compounds of nitrogen.

If the air were pure oxygen, fires could not be controlled and things would oxidize too rapidly. Thus, another important use of nitrogen is to restrain the activity of oxygen and make the atmosphere suitable for life.

Hydrogen

Where it is Found. Hydrogen (H) occurs combined in water, plant and animal tissue, wood, coal, gas, and all acids.

Properties. It resembles both nitrogen and oxygen in being a colorless, odorless, and tasteless gas. It does not dissolve much in water and it will not cause things to burn, but unlike either nitrogen or oxygen it burns readily and even explodes when mixed with air and brought into contact with fire. It is the lightest substance known and, because of this fact, is used to fill balloons.

Uses. Hydrogen is important to the biologist because it unites readily with oxygen and forms water. It also combines with both oxygen and carbon (another element) and forms a whole series of compounds called fats, sugars, and starches. It is an essential ingredient in all organic tissue.

Carbon

Carbon (C) is an element with which we are more familiar; coal, charcoal, and wood are common forms. Lead-pencils do not really contain lead at all but another form of carbon called graphite. Strangest of all, the diamond is carbon, too, though not a common form.

Properties. Carbon is (except in the diamond) a black insoluble solid. At ordinary temperature it is very inactive. When heated, however, it unites readily with oxygen, (that is, it burns) and forms an oxide which is called *carbon dioxide*—a compound very necessary to plants, as we shall see later.

Uses. Carbon's importance to biology is due to the fact that it is a part of all organic substances, combining with hydrogen, nitrogen, and oxygen and other elements to form all plant and animal tissues and many of their foods.

We know that if any plant or animal substance is partly burned a black solid is produced. This, in every case, is carbon. We also know that if the burning is continued the carbon will disappear. This means that it becomes oxidized into carbon dioxide, which is an invisible gas.

Plants *alone* have the power to obtain their carbon from the carbon dioxide of the air. Animals depend entirely on plant foods for the carbon compounds which are necessary for their life.

Sulphur

Sulphur (S) is a yellow solid element, which (like carbon) will not dissolve in water, but can be dissolved in other chemicals.

Sulphur itself has no odor. It readily unites with oxygen, even at low temperatures, and it also burns readily, producing in both cases an oxide of sulphur (SO_2) with the familiar, suffocating odor which we wrongly associate with sulphur itself.

Its importance in biology is due to the fact that it is a part of the living substance of all organic things though in smaller amounts than any of the preceding elements.

Mustard, onions, and eggs will blacken silver dishes. This is due to the sulphur compounds which they contain; but sulphur, in smaller quantities, is found in all plants and animals.

Phosphorus

Phosphorus (P) is a light yellow, waxy, solid element. Like sulphur, it dissolves in several other liquids, but not in water. It also resembles sulphur in that it unites readily with oxygen. In fact it unites with oxygen more readily than does sulphur, for, if exposed to air, it will take fire and burn fiercely, forming an oxide of phosphorus. It has to be kept covered with water to prevent it from burning and is a dangerous and poisonous element.

It seems strange that such a substance should be a necessary ingredient of our bodies and, in fact, of all living things. To be sure it is present in small amount but is absolutely essential, being especially abundant in bone and nerve tissue.

You have probably heard plant fertilizers called "phosphates." This is because they contain phosphorus compounds.

Iron

Iron is another element. We are familiar with it as a heavy, solid metal; and we know it unites slowly with oxygen forming iron oxide (rust). This is about the last thing we would think to be of use in the bodies of plants or animals. However, iron is associated with the green coloring matter of plants and is contained in the red blood of animals. Later we will learn the remarkable services which its compounds perform in these substances.

Sodium, Potassium, and Calcium

Our list of elements important to organic life will end with three similar ones: sodium, potassium, and calcium. The first two are light, metallic substances which burn when put in water and are therefore very dangerous to handle. Calcium is somewhat less active. Potassium compounds must be in the soil if plants are to thrive, while sodium and calcium compounds are necessary for the blood and skeleton of animals.

Nitrogen, sulphur, phosphorus, iron, sodium, potassium, and calcium are all obtained from their mineral compounds in the soil. Animals use salt (a sodium compound) directly, while they get the other elements from plant foods. Plants in turn obtain them from the soil.

By themselves, all these elements are inorganic substances, but in the wonderful process of assimilation, plants and animals can combine them to form the living stuff of which their tissues are made. On the other hand, by the processes of oxidation, death, and decay, the complex organic compounds are broken up into simpler forms, and return to the soil or air

as inorganic compounds or elements, to be used over again by organic things.

Here is an estimate of the composition of the human body, which may give an idea of the comparative amounts of the different elements in animal tissue.

A person weighing 154 pounds would be composed of:

Oxygen	97.2	pounds
Carbon	31.1	"
Hydrogen	15.2	"
Nitrogen	3.8	"
Calcium	3.8	"
Phosphorus	1.75	"
Sulphur	.27	"
Chlorine	.25	"
Fluorine	.22	"
Potassium	.18	"
Sodium	.16	"
Magnesium	.11	"
Iron	.01	"

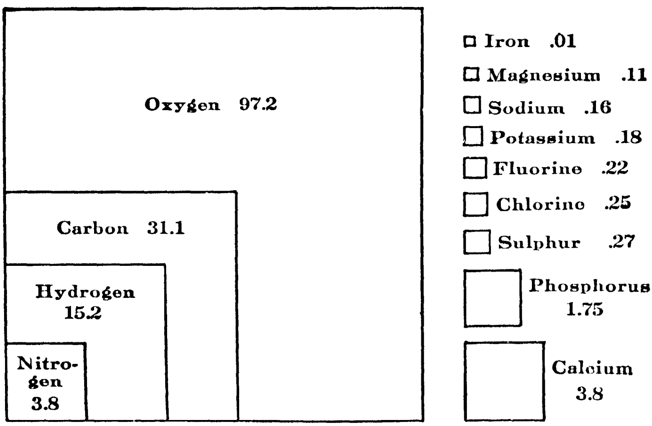

FIG. 1. Elements composing a human body weighing 154 pounds. (Figures express pounds.)

COLLATERAL READING

See index of any text book in Elementary Chemistry. *Applied Biology*, Bigelow, pp. 5–9.

Some Elements of which Living Things are Made

Element	Where found	Properties	Uses	Test
Oxygen	Air, water, soil (1/5 of air)	Gas, colorless, odorless, tasteless, soluble, very active, causes things to burn, oxidizes	Respiration, combustion, decay, releases energy	Causes glowing splint to burst into flame
Hydrogen	Water, organic tissue	Gas, colorless, odorless, tasteless, very light, burns, explodes, extinguishes flame	Component of all nutrients and organic tissues, part of water	Explosion when mixed with air and lighted
Nitrogen	Air, soil, nitrates, proteins (4/5 of air)	Gas, colorless, odorless, tasteless, neither will burn nor cause things to burn, inactive	Supply nitrogen compounds for soil and all active tissues	Extinguishes flame and does not turn limewater milky
Carbon	Organic tissue, coal, graphite, wood, etc.	Solid, black, insoluble, burns, forming CO_2	Component of all nutrients and organic tissues	Production of CO_2 when burned
Sulphur	Mineral compounds, proteins, eggs, mustard, etc.	Solid, yellow, insoluble in water, tasteless, burns forming SO_2	Essential in protoplasm and bone tissue	Odor of SO_2 when burned
Phosphorus	Mineral compounds, phosphates, bone	Solid, waxy, yellow, burns readily, poison	In protoplasm, seed, nerve, and bone	Ease of burning
Iron	Soils, ores	Solid, heavy, white, oxidizes or "rusts"	For action of chlorophyll and red part of blood	Its properties Unburned ash
Calcium Sodium Potassium	Rock, soils, salt, limestone, etc.	Solids, soft light metals, react with air and water	Compounds essential in blood, bone, and plant tissues	Flame colors: Sodium, yellow Potassium, violet Calcium, orange

CHAPTER IV

COMPOUNDS, BIOLOGY'S BUILDING MATERIALS

Vocabulary

Dynamo, a machine for changing mechanical power into electrical energy
Conservation, the act of keeping from loss.
Ingredient, part.
Identity, state of being the same.
Composition, the state or manner of being put together.
Nutrient, food.

Matter and Energy. Anything which occupies space and has weight is called "matter." The elements are the simple substances of which matter is made. Elements may be merely mixed in any proportions or they may be united into compounds by chemical energy.

Energy is the ability to do work. There are many ways in which energy shows itself, as in heat, light, and electricity, and in mechanical and chemical changes.

When we build a fire under a steam boiler, we set free the chemical energy of the wood and change it into heat energy. The heat energy sets the water particles in motion and we have steam. The energy of steam in the engine is converted into mechanical energy (motion) and may in turn run a dynamo. The dynamo can convert the mechanical energy into electricity and energy which, in turn, we may conduct into a lamp, changing it into light.

Thus the energy has been changed from one kind to another but has not been destroyed. Some is lost because of the poor operation of our apparatus, but none is actually out of existence. This fact has been so thoroughly proven that it is stated as a "law," called the Law of Conservation of Energy. This merely states the fact that energy cannot be created nor destroyed, but can only be changed from one form to another.

The elements are held together by chemical energy to form compounds. When elements or compounds are oxidized, their energy is set free. We may use it for fuel under our boiler or for food in our body. In either case we convert the energy of the food or fuel into other sorts of energy and these in turn do work in other ways. The engine turns a machine or the body lives and moves. Energy is involved in both cases though something more than mere chemical energy is needed to produce life.

Compounds and Mixtures. A compound is a substance composed of two or more elements combined in definite proportions by weight. The compound is held together by chemical forces and cannot be separated except by the use of chemical energy. Furthermore, the elements composing the compound have lost their identity and no longer have the appearance or properties that they had before they were combined.

A mixture, on the other hand, may be composed of two or more elements or compounds (or some of each) *not* in definite proportions by weight and *not* held together by chemical force. The ingredients of the mixture can be separated *without* the use of chemical means. Each ingredient in a mixture retains the properties which it had when alone.

A Mixture. For example, we can mix powdered iron and powdered sulphur in any proportions we wish. Having mixed them we can take a hand lens and see the separate particles of iron and sulphur, just as they were before mixing. We can pick out the iron with a magnet or remove the sulphur with suitable substances which will dissolve it and leave the iron. So far we have only a *mixture.*

A Compound. Now if we put this mixture in a test-tube and heat it strongly, a glow will spread through the mass and a very different substance will be found in the tube after it cools. To begin with, heating caused the iron and sulphur to combine chemically. They no longer can be seen as iron and sulphur when we look with the lens, nor can we remove the iron or the sulphur as we did before.

The heat has produced a chemical change which has caused

the iron and sulphur to lose their identity and unite to form a *compound* called iron sulphide which has properties differing from those of either iron or sulphur. So closely are they united that chemical means would be needed to get them apart again. Another curious thing about a compound is that its parts are in fixed proportions by weight. In this case, 56 parts of iron will combine with 32 of sulphur and if we have different proportions in the mixture, some will be left uncombined.

In living things, most of the elements are found united in various compounds, seldom in mixtures. Some of the compounds are simple in composition like water, which has eight parts of oxygen and one part of hydrogen by weight; others, like the proteins, are so complicated that it is hard to state their composition.

COMPARISON OF MIXTURE AND COMPOUND

Mixture	Compound
Elements present as such	Elements lose identity
Properties are average of the ingredients	Properties different from those of ingredients
Not produced by chemical change	Produced by chemical change
Separated by physical means	Not separated by physical means
Proportions variable	Proportions fixed

Chemical Changes. A compound may be formed or decomposed by chemical means and such changes are called *chemical changes.* Chemical changes always produce new kinds of substances and often set free heat or some other kind of energy, which in many cases is very important to living things.

The chemical change called oxidation is essential to all living things. Digestion of food involves chemical changes without which life could not exist. Assimilation, respiration, excretion, and many other biological processes involve chemical changes some of which are most complicated.

Physical Changes. Another kind of change that goes on in the world around us is called *physical change.* In a physical change no new substance is formed but the appearance of the substance may be temporarily altered. When water freezes it

becomes ice with different properties from water, but the water is still unchanged in composition and will reappear when the ice melts.

The Conservation of Matter. When wood burns, a chemical change takes place. The carbon of the wood unites with the oxygen of the air forming the compound, carbon dioxide, and the hydrogen from the wood also unites with oxygen, forming water. We say the wood "burns up" and it surely does seem to disappear, but really it has only been changed into new compounds. It is possible to weigh the carbon, the hydrogen, and the oxygen and to prove that nothing has been destroyed; the elements have been arranged in different compounds, that is all.

This has been so carefully proven that the fact is stated as a chemical "law" that matter is not destroyed nor produced by chemical or physical changes. Its other properties may be changed but weight is neither gained nor lost. This is called "The Law of Conservation of Matter."

Elements and compounds may exist in either of three conditions, as solids, liquids, or gases. The condition usually depends on the temperature or pressure of the substance. Thus water may exist as a solid, ice, or as a liquid, water, or as a gas in the form of steam. Iron is usually a solid, but can be melted to a liquid state, and can even be vaporized. Oxygen is usually a gas but can be liquefied or even made into a solid, somewhat like snow. These conditions, solid, liquid, and gas, are known as the *three states of matter* and are usually mentioned as among the properties, when elements or compounds are described.

We have learned the names and something about the characteristics of a few of the elements. In dealing with these elements and their compounds it is necessary to find some way to distinguish one from another, in order that they may be properly studied.

Method of "Testing" Substances. Such means of distinguishing are called "tests" and we have already referred to one in the case of oxygen. The test consisted in the fact that oxygen, and *no other substance,* would cause a glowing spark to burst into flame.

Before taking up any test three things must be considered.

1. A substance known to be the one we are studying must be tested, so that we may know the correct result, and be able to recognize it in an unknown case.

2. The test must be true of the substance sought, and of *no other*. You can readily see, that if even one other gas would kindle the glowing splinter, then that could not be used as a test for oxygen.

3. The test must be made in the same way, every time, or else one might suppose that the result was affected by the difference in treatment.

Inorganic Compounds

Carbon Dioxide. When carbon unites with oxygen, it forms a colorless, odorless, and tasteless gas called carbon dioxide (CO_2), which is heavier than air and will extinguish a flame.

Carbon dioxide is like nitrogen in many ways (mention them), but if it be mixed with *lime water*, it causes the clear liquid to become *milky*, while nitrogen does not. This is the test for carbon dioxide.

Carbon dioxide is a source of plant food; plants have the power to take this gas from the air, combine it with water, and make it into their tissues—in fact it is from this source that all organic carbon comes.

Water. When hydrogen combines with oxygen, water (H_2O) is formed as we found when studying hydrogen. This compound is so familiar that we do not need to learn any test for its presence. It may be well to realize, however, that water constitutes much over half the weight of all organic matter and that it is absolutely essential to all life. It is not only a food, but a means of carrying food to the tissues of all plants and animals.

Mineral Compounds. The next compounds we shall take up are made of the elements mentioned last in our list: sulphur, phosphorus, iron, potassium, sodium, and calcium.

Calcium unites with sulphur and oxygen to form calcium sulphate, and with phosphorus and oxygen to form calcium phosphate. Sodium and potassium unite with oxygen or nitrogen

to form sodium or potassium nitrates and so on with many other compounds.

Fortunately we do not have to learn to test for these separately. When found in organic tissue, they are usually grouped together and called "mineral matter" or "mineral salts," and the fact that they remain as ash, when organic matter is completely burned, is a sufficient test for these compounds at present.

Notice that all the elements except carbon and hydrogen may exist, combined as mineral compounds, in the soil where the plants can get them. Hydrogen is obtained from *soil water* and carbon from the carbon dioxide of the air. All the compounds mentioned so far, water, carbon dioxide, and numerous mineral salts, are inorganic substances.

One of the most important ways in which plants differ from animals is that plants can use inorganic substances for food and recombine them into organic compounds.

Though animals use water and some mineral salts, they depend for their life on the organic compounds made by the plants. Flesh-eating animals live on other animals, which in turn use plant food.

Plants require food just as definitely as do animals. Not only must they have water and carbon dioxide, but certain mineral compounds as well. If these are not already in the soil, they have to be supplied artificially if plant crops are to grow. This additional plant food is called "fertilizer" and may contain compounds like nitrate of soda, which will supply nitrogen in useful form, or the fertilizer may contain calcium phosphate which will give the plants the necessary phosphorus and calcium. In a similar way potassium compounds (usually referred to as "potash") are added to supply potassium for plant growth. It should be noted that plants cannot use the elements by themselves, but only when in suitable compounds; phosphorus alone would make a sorry fertilizer, but phosphates are essential in any fertile soil. Also it should be borne in mind that a soil may lack only one or two of these compounds and plant foods are added only after analysis of the soil has been made.

Organic Compounds. Nutrients

Fortunately, the very complicated compounds which both plants and animals use for food and growth, can be grouped into three great classes called: (1) Proteins, (2) Carbohydrates, (3) Fats. These are sometimes grouped together and called *organic nutrients.*

A fourth class of substances called *vitamins* should be added to this list, as they seem to be essential to healthy growth, at least in man and higher animals. Their composition is not fully known and they will be discussed in more detail in the chapter on foods.

Proteins. These are very numerous and are found in all living substances; the following are some that are common and found in large amounts:

Protein	*Where found*
Gluten	in grains
Legumin	in peas and beans
Myosin	in lean meat
Albumen	in the white of egg
Casein	in milk and cheese

It is not necessary to learn these names but the list is put in to show that proteins are of many kinds and, though first provided by plants, are needed in animal tissue as well.

Test for Proteins. Proteins differ in many ways but there is one point in which they all behave alike and which is different from any other substance—hence we can use it as a test. If a substance supposed to contain any protein is put into *nitric acid* and *heated* gently, it will turn bright yellow. Then if the acid be washed off and *ammonia* added, the protein, if present, will become *orange* color. This is the test for any protein as no other substance will act in the same way.

The proteins are the most useful of the nutrients for they make up most of the active living substance of plant and animal; they are called tissue builders on this account. Proteins are composed of the elements carbon, hydrogen, oxygen, nitrogen,

sulphur, phosphorus, with sometimes mineral salts as well, so we see they are very complex organic compounds.

Carbohydrates. Next to proteins in importance to all living things come the carbohydrates. They are composed of carbon, hydrogen, and oxygen, with always twice as much hydrogen as oxygen, and varying amounts of carbon.

Carbohydrates are found almost entirely in plants, whose tissues they largely compose. When animals eat them, they usually oxidize them as fuel to produce heat and energy. Some are converted into fats and stored as such.

Some common carbohydrates are:

The starches.

Corn starch	from	corn	
Potato starch	"	potato	
Flour starch	"	wheat	
Tapioca starch	"	cassava root	

The sugars.

Cane sugar	"	sugar cane	(saccharose)
Beet sugar	"	sugar beet	(saccharose)
Grape sugar	"	fruits	(glucose)
Milk sugar	"	milk	(lactose)

Cellulose.

Complicated forms found in wood, paper, cotton, linen.

Glycogen is an animal carbohydrate found in the liver of some animals and called "liver starch." It seems to be stored there for later use.

It is a little strange to think of cotton and starch, or wood and sugar as being so nearly related, but they consist of the same three elements, and are produced by the plants from water and carbon dioxide. It would be a cheap diet, if we could take water from a reservoir and carbon dioxide from the air and make them into flour. Man has to depend on plants for this wonderful process, and can only begin where the plants leave off, using the plant-made carbohydrates for his food.

The Test for Starches. No one test can be used for all the carbohydrates, but we can test for any starch by dissolving the

substance supposed to contain it in hot water, cooling the solution, and then adding a drop of *iodine*. The solution will turn blue if starch be present. No substance other than starch will act this way under these conditions.

The Test for Grape Sugar. There is no one test for all sugars, but grape sugar (glucose) is very common and can be easily distinguished from our household (beet or cane) sugar by what is known as the *Fehling test*—so named from the man who devised it.

Two solutions are used in the Fehling test, one *colorless*, and one *blue*. When these are added in equal amounts to a similar amount of the substance to be tested, and the mixture *heated*, a *yellow-brown solid* will form if grape sugar be present. Cane or beet sugar will not act this way.

Fats. The last class of nutrients is the fats and oils, which are also composed of carbon, hydrogen, and oxygen. They differ from carbohydrates in having less oxygen. Hence they oxidize more readily and as a result their chief use is to produce energy.

Plants store fats in their seeds to supply energy for growth; animals store fats in various places and use them for the same purpose.

Kinds. Cotton-seed oil, olive oil, and the oils from various nuts are examples of vegetable fats. Lard, butter, and fat meats are familiar examples of fat from animals.

Test for Fats and Oils. The substance should be crushed as finely as possible and treated with ether, or carbon tetrachloride ("carbona"). This will dissolve out any fat or oil that may be present and the solution can then be poured off. When the ether evaporates the fat will remain in the dish.

COLLATERAL READING

See index of any Chemistry Text for the Compounds mentioned. *General Biology*, Sedgwick and Wilson, pp. 33–40; *Biology*, Bailey and Coleman, Introduction; *Chemistry of Plant and Animal Life*, Snyder, see index; *Source, Chemistry and Use of Food Products*, Bailey, pp. 1–24; *Food Products*, Sherman, pp. 1–23; *Botany for Schools*, Atkinson, pp. 13–19.

SUMMARY OF CHAPTER IV

COMPOUNDS

1. Element (see Chapter III).

2. Compound.
- a. Characteristics.
- b. Distinction from mixture.

3. Mixture.
- a. Characteristics.
- b. Distinction from compound.

4. Changes.
- a. Chemical change.
- b. Physical change.

5. Matter and Energy.
- a. Conservation of energy.
- b. Conservation of matter.
- c. States of matter.

COMPOUNDS OF WHICH LIVING THINGS ARE MADE

Compound	Composition	Kinds	Where found	Use	Test
Inorganic					
Mineral salts	Potassium, sodium, calcium, N, S, P, iron	Phosphates, sulphates, nitrates, etc.	Soil, bone, seeds	Furnish N, S, P, etc., for protoplasm, supporting tissue	Remains as ash when compound is burned
Water	H_2O		Soil, air, organic tissue	Solvent, carrier, plant and animal food stuff	
Carbon dioxide	CO_2		Air	Plants make food of it (starch)	Turns limewater milky
Organic					
Proteins	C, H, O, N, S, P	Gluten Myosin Albumen Casein Legumin	Grains Lean meats Eggs Milk, cheese Peas, beans	Tissue building Making protoplasm	Add nitric acid, heat causes yellow color Wash and add ammonia, color deepens to orange
Carbohydrates	C, H_2, O	Starch Sugars: sucrose glucose lactose Cellulose	Corn, wheat, potato Cane, beet Grapes, honey Milk Wood, paper, linen	Plant tissue, animal food for energy Energy-making food Plant tissue	Turns blue with iodine For glucose: brown color with Fehling test
Fats	C, H, O	Plant: olive oil cotton-seed oil nuts Animal: butter lard, meats	 Olives Cotton-seed Peanuts Milk Pork, beef	 Energy-making foods Stored as fat	 Crush, dissolve in ether and let ether evaporate, fat remains

CHAPTER V

PROTOPLASM, THE "BIOS" OF BIOLOGY

Vocabulary

Fundamental, that upon which all else is built.
Nucleus, most active part of cell protoplasm, controls growth and reproduction—usually visible as a denser spot.
Transmission, act of handing down, transferring.
Granular, like grains.
Function, use or work of a special part.
Adaptation, fitness for use.
Environment, all that makes up the surroundings of any living thing.

Since it appears that plants and animals are composed of the same elements and use similar compounds for food it would be only natural that their foundation material should be the same. This is, in fact, the case. The foundation substance is called *protoplasm,* a name derived from two Greek words, *protos* (first) and *plasma* (form or substance). It is well named, for it is the first and most necessary substance of all organic things.

Protoplasm is *alive* and, in truth, the *only* living substance. We do not know what life is but we do know that as long as life exists in plants or animals, their protoplasm is active. When it ceases to act, death is the result.

Protoplasm may be defined as the fundamental, essential, living substance of all plants and animals. It is a jelly-like substance composed of carbon, hydrogen, oxygen, nitrogen, sulphur, and phosphorus; but while we can analyze it and state its composition, we cannot combine the elements to make it.

Because it is alive, protoplasm has certain remarkable properties:

1. It takes in, digests, and assimilates food.
2. It oxidizes food and excretes waste.
3. It grows in size and form.
4. It has power of motion.
5. It responds to light, heat, moisture, etc.
6. It reproduces.

We observe that this list is much like the one which gave the points in which the cat resembled the geranium. Now we can see the reason: both depend on protoplasm for life, so, of course, their life processes would be similar.

The Cell. In most plants and animals the protoplasm is divided into very small parts called *cells*. These may be defined as the simplest units of protoplasm of which living things are composed.

Structure. A cell usually consists of a tiny mass of protoplasm which may or may not be surrounded by a cell membrane or wall. In plant cells the wall is generally present and is composed of a substance called cellulose which is not found in animal cells. Animal cells may have a cell membrane, but it is not called a "cell wall" in the same sense as those found in plants.

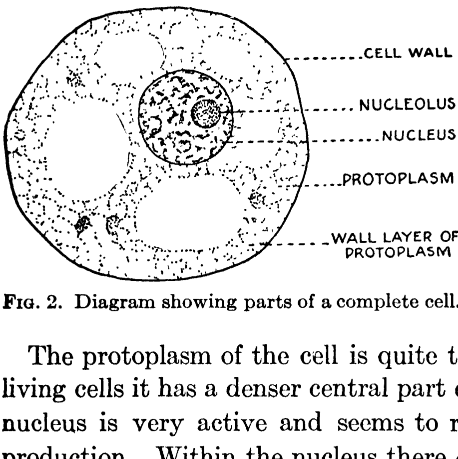

FIG. 2. Diagram showing parts of a complete cell.

The protoplasm of the cell is quite transparent, but in most living cells it has a denser central part called the *nucleus*. This nucleus is very active and seems to regulate growth and reproduction. Within the nucleus there can sometimes be seen a darker portion which is called the *nucleolus*. When stained for microscopic study, there appears in the nucleus a substance called *chromatin* which has to do with the transmission of hereditary characteristics.

The protoplasm outside the nucleus is called *cytoplasm*. It may show a granular appearance if greatly magnified, and is sometimes seen to be arranged in a layer next to the wall, another layer around the nucleus and strands connecting these two regions; in other cases the cytoplasm is more evenly distributed and may show spaces like bubbles of clearer substance, called *vacuoles*.

Small as they are a typical cell might have the following parts:

1. Cell wall or membrane.
2. Protoplasm.
   (a) Cytoplasm variously arranged.
       Granules and vacuoles.
   (b) Nucleus.
       Nucleolus.
       Chromatin.

The Cell as a Unit. Cells are usually very small, though some are large enough to be seen without a microscope. They vary greatly in shape according to the work they perform. A house might be built of bricks or stones, or concrete blocks depending on the purpose for which it was intended, but in any case, the brick, stone, or block would be the unit of which the wall was made. In the same way, cells are the units of which are constructed the living things which we study in biology.

Some plants and animals consist of only one cell. In more complicated animals, there are a great many different groups of cells, each fitted for some one purpose, as, for example, the vast number of cells that together make up a muscle and have developed especially the power of motion.

Cell Growth. Living cells have the power of growth, but the size of any single cell is limited and when that limit is reached the cell usually divides in two and growth continues. This is a complicated process. Changes take place inside the nucleus, then it divides, and finally the protoplasm of the cell separates in two portions, each with a new nucleus, and two cells exist where there was formerly but one. This power of growth and division is characteristic of protoplasm and is the foundation of the activities of living things. The rate of cell growth and division is often very high and the total numbers reached are so great as to be beyond comprehension. A drop of blood may contain five million blood cells, yet the loss of many drops of blood is not a serious matter, and they are soon replaced. The

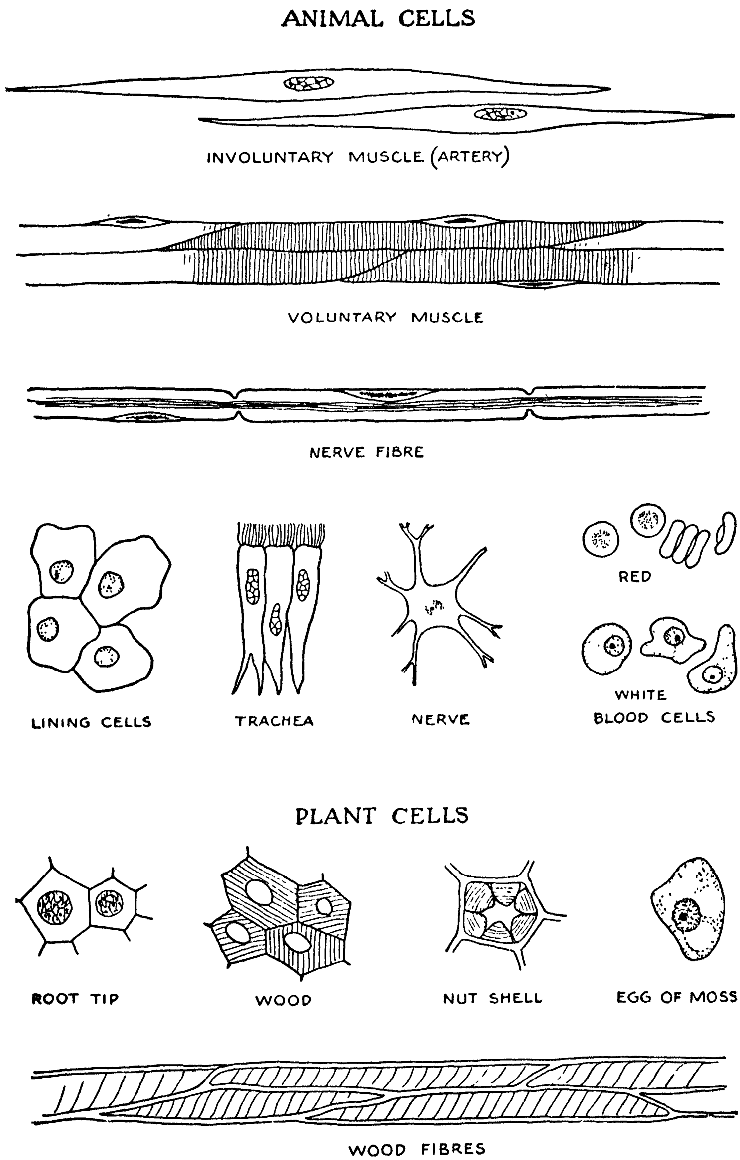

FIG. 3. Animal and plant cells from various tissues.

development of a sprouting seed or the ordinary growth and repair of our own body means the production of countless cells.

Not only are new cells produced but they become fitted for different purposes. The growing seedling soon has root cells and stem cells and leaf cells, each adapted for its particular kind of work.

Cells, though small, are not weak. The strength of the elephant is but the total strength of his muscle cells. The developing cells of a tiny seedling often lift masses of earth many times the weight of the plant. The growing cells of tree roots lift pavements and split rocks.

Tissues. A group of similar cells, devoted to a single use, is called a *tissue.* There are many kinds of tissues, as wood, bark, and leaf, in plants; and bone, muscle, nerve, etc., in animals.

Organs. In all the more familiar plants and animals, various tissues are grouped together to form a more complex part, which has some important general use. The stem of a tree, for instance, whose use is to support the leaves, flowers, and fruit, consists of wood, pith, bark, and other tissues, all working together for one purpose. The leg of a cat is made up of bone, muscle, nerve, and other tissues, working together to make locomotion possible. Such groups of tissues are called *organs* and the purpose or use of any part is called its *function.*

So we can say that all living things are composed of protoplasm; the protoplasm is usually divided into cells; the cells are grouped into tissues, and these, in turn, into organs fitted for some particular function or functions.

Systems. Often in the higher forms, especially among animals, several organs are grouped together to perform related functions. Such groups are referred to as *systems*, as, for example, the circulatory system, which includes the heart, arteries, veins, and capillaries. These are organs, all united in the work of circulation.

The comparison is sometimes made between a plant or animal and a book, as follows:

The elements	correspond to	the letters.
Compounds	correspond to	words.
Cells	correspond to	sentences.
Tissues	correspond to	paragraphs.
Organs	correspond to	chapters.
The plant or animal	corresponds to	the whole book.

To illustrate this method of structure we may look at the hand. It is made of millions of *cells*, as shown by the microscope, each having its characteristic shape and each composed of protoplasm and nucleus.

Numerous as these cells are, they can be classified into a comparatively few kinds. Groups of similar cells are called *tissues*, and we find in the hand, muscle tissue, bone tissue, nerve tissue, skin tissue, and some others. Each of these tissues has its special use. The muscle is used for motion; the bone, for support; and so on. All together they are combined into one *organ*, whose general function is prehension (grasping things).

In a similar way with plants, the *cell* is the unit of structure, and in a stem, for instance, there are several kinds of cells. These are grouped into wood *tissue*, bark tissue, tubular tissue, and pith tissue, each made of similar cells and each with different functions. However, they are all grouped together to form the plant *organ*, called the stem, with its general functions of support and circulation of sap.

Relation of Structure to Use. Organic things are composed of the same elements, combined in similar compounds, which appear as living protoplasm, whether of animals or plants. This protoplasm performs very similar functions in either case, but by very different organs. The plant gets its food by way of leaves and roots. An animal like the cat uses its claws, teeth, and swiftness in food getting. Our whole course in biology deals with the essential life functions of plants and animals, but, in order to study these functions intelligently, we must first know something of the structure of the organs concerned in their performance.

As soon as one understands structure in its relation to function it becomes apparent that each organ is wonderfully fitted for

its particular work. This fitness of structure to function is called *adaptation*, and is a very important topic in all biologic study. Structure, function, and adaptation are the foundation stones of our subject and will always be presented in the order here named. We shall study both plants and animals with the idea of learning how their structure adapts them for the functions which both have in common and shall begin with plants, because, while their functions are similar to those characteristic of animals, their structure is much simpler. The following functions are common to both plants and animals:

Food getting	Respiration
Digestion	Excretion
Circulation	Motion
Absorption	Sensation
Assimilation	Reproduction

Factors of Environment. Not only do both plants and animals perform similar vital functions, but in general they require certain similar conditions or surroundings. Living things, whether plant or animal, require air, food, and moisture. Light is essential in most cases and a rather definite range of temperature must be provided, if life is to continue.

Often there are more particular factors which must be present if a certain plant or animal is to survive. Water plants and animals require water and die when removed from it. Desert life would not survive in arctic surroundings. Many flowers depend on certain insects for carrying pollen and will not form seed unless these insects are present to help. The list might be indefinitely increased. The peculiar relationships between living things and their surroundings form one of the most interesting topics in all biology.

The word "environment" is used to include all the conditions that surround any organism. Plants and animals are in general fitted by nature to their environment and may be unable to exist in different surroundings. Man has learned to control his environment, or adjust himself to it so that he can

exist in a very wide range of conditions. By teaching about the life processes of plants and animals, biology aids man to regulate his environment by adjusting the habits and relationships of living things to serve his needs.

Adjustment to environment plays a large part in biological science. The gradual fitting of a plant or animal to its condition of life is often very wonderfully carried out. Economic biology deals with the use that man has made of his living environment in the way of food, clothing, shelter, and transportation. Modern medicine and hygiene is often concerned with protecting man from factors in his surroundings which would produce disease. Agriculture is largely based on providing proper environment for useful plants and animals. The more one can know of living things and how they are related to each other and to man, the better he is equipped to cope with his own environment. This is one reason for the study of biology.

COLLATERAL READING

General Biology, Sedgwick and Wilson, pp. 20–32; *Applied Biology*, Bigelow, pp. 39–44; *Botany for Schools*, Atkinson, pp. 33–36; *Botany of Crop Plants*, Robbins, pp. 4–9; *Fundamentals of Botany*, Gager, pp. 14–20; *Plant Anatomy*, Stevens, 1–10; *Plant Physiology*, Duggar, pp. 15–32; *College Botany*, Atkinson, pp. 1–12; *Biology*, Calkins, pp. 6–25; *Encyclopedia Britannica*, articles on "Physiology," "Protoplasm," "Protozoa."

SUMMARY OF CHAPTER V

PROTOPLASM

1. Protoplasm.

- a. Derivation of the word.
- b. Definition.
- c. Composition.
- d. Properties.
  - (1) Takes, oxidizes, and assimilates food.
  - (2) Excretes waste.
  - (3) Grows.
  - (4) Moves.
  - (5) Responds to light, heat, etc.
  - (6) Reproduces.

2. The cell.

a. Definition.
b. Structure.
    (1) Protoplasm.
        (a) Nucleus.
        (b) Cytoplasm.
    (2) Wall (if present).
c. Function.
    (1) All the properties under Protoplasm, **4.**
    (2) Controls growth and reproduction.
    (3) Supports and gives form to cell.

3. Tissue.

a. Definition.
b. Examples.

4. Organ.

a. Definition.
b. Examples.

5. System.

a. Definition.
b. Examples.

6. Adaptation.

a. Likeness of functions in living things.
b. Difference in structure.
c. Fitness of structure for function.
d. Order for study.
    (1) Structure.
    (2) Function.
    (3) Adaptation.

7. Definitions.

a. Protoplasm is the primary, essential living substance of all plants and animals.
b. A cell is the simplest unit of plant or animal structure.
    It consists of protoplasm, nucleus, and (sometimes) cell wall.
c. A tissue is a group of similar cells having a special function.
d. An organ is a group of various tissues having a general function.
e. A system is a group of organs concerned in one or more related functions.

CHAPTER VI

THE STRUCTURE OF SEEDS

Vocabulary

Immature, not fully developed.
Primitive, simple or early form of an organ.
Transmit, to carry (similar to transport).
Modified, changed for different use.

We know already the names of the principal organs of a plant—the root, stem, leaves, flower, fruit, and seed—and understand in some measure the functions performed by each. We must also remember the varied surroundings of the plant, the kind of soil, amount of moisture, temperature, insect enemies, and all that goes to make up its conditions of life (environment). In our study we shall start, as the plant starts, with the seed. Then we will follow its growth, and the development, structure, and use of the different plant parts mentioned above.

It is so common a fact that a seed reproduces the whole plant that the wonder of it is often overlooked. In the seed must exist, alive, all the beginnings for the full-grown plant, together with nourishment to start growth and sufficient protection.

The seed, then, is a plant organ which consists of three parts: the immature plant (embryo), stored food, and protective coverings.

Seed Coats. The outer covering of most seeds is called the *testa*, and is usually thick enough to protect from injury by contact, moisture, or insects. It may also have special adaptations for dispersal. A second inner thin coat (tegumen) is present in some seeds.

Since the seed was once a part of the parent plant, it bears a scar on the testa, called the *hilum*, which marks this point of previous attachment. Near this scar is usually visible a tiny opening called the *micropyle*, from two Greek words meaning "little door." This little door has two uses; it lets the pollen

tube enter the seed when it is fertilized (see Chapter XIV), and it lets the young plant out when it begins its growth.

Kernel. Within these coats is the kernel or seed proper. It may consist wholly of the undeveloped plant (embryo); or may have, *outside* the embryo, a store of nourishment called the *endosperm.*

Embryo. If endosperm be present, the embryo may be poorly developed, even showing no sign of its usual parts, as in the orchids. On the other hand, the embryo may be highly developed and show well-defined stem and leaves, as in the bean; for since there is no endosperm in the bean, the plantlet must seek its own nourishment very early. The embryo, or miniature plant, consists of three parts: the *cotyledons*, *plumule*, and *hypocotyl.*

Cotyledons. These are the seed leaves or the first leaves of the plant and, though often not resembling ordinary leaves either in appearance or use, still they play a very important part in the early growth of the seedling. They may be really leaf-like and come up when the plant begins to grow, forming true green leaves, as in the squash. In this case they are thin and have little stored food, because they get all they need as soon as they rise above the soil. On the other hand the cotyledons may be so well supplied with food that they cannot act as leaves at all, merely coming above ground, giving over their stored food to the growing seedling, and then withering and dropping off, as is the case with most beans. In other cases, such as the pea, the cotyledons are so greatly enlarged with food, that they cannot be lifted from the soil at all, and so supply the plant from their place in the ground below. In cases where the food is stored outside the embryo as the endosperm, the cotyledon often re-

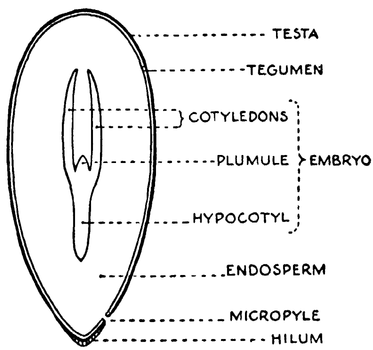

FIG. 4. Diagram showing internal structure of a typical seed.

mains in contact with it to digest and transfer food from endosperm to embryo, as is the case in corn.

Not only do the cotyledons vary in size and use (function), but also in number, there being only one in many plants such as corn and other grasses, lilies, palms, etc., two in many common plants like the bean, squash, apple, and buttercup, and many in pines and other evergreens. So important is this difference that all plants that bear seeds are classified as:

Monocotyledonous (having one cotyledon)
Dicotyledonous (having two cotyledons)
Polycotyledonous (having three or more cotyledons)

The plants in each of these three divisions are usually similar in structure of stem, leaf, and flower.

Plumule. The plumule is that part of the embryo above the cotyledons, from which develops the shoot proper, consisting of stem, leaves, and flowers. It may vary much in size and development. If much food be stored, either in cotyledons or endosperm, the plumule may be small. On the other hand if little food be provided, the plant must early shift for itself, and so the plumule may have several well-formed leaves, wanting only exposure to light to become a self-supporting plant.

Hypocotyl. The primitive stem, or all that part of the embryo below the cotyledons, is the hypocotyl. From its *lower* end the root system develops. Upon its *upward* lengthening depends whether the cotyledons shall emerge from the soil when germination takes place.

Endosperm. Though the endosperm is usually present at some stage, it is not found in all seeds when they are mature. It may be entirely absorbed by the growing embryo, its function of food storage being assumed by the cotyledons. It is, however, very important in many seeds, especially the grains. From its store of starch we derive our bread. Food for the embryo may be stored either in the endosperm or cotyledons. Our laboratory tests show that this stored food consists largely of starch, together with considerable protein, a little fat or oil, and some mineral matter.

The seed has within itself the miniature plant, or embryo, and all the kinds of nutrients needed for growth except water. This the seed must get from the soil before it can grow. The growth of a seed is a wonderful process. Though inactive, dry, and apparently dead the protoplasm is really alive and only awaits favorable conditions for growth to begin.

The insoluble, stored foods must be digested by the embryo, made soluble, united with the water which has been absorbed from the soil, and assimilated, to form all the new kinds of tissue in the growing seedling. It may seem strange to speak of a seed as digesting food, but there is a substance (diastase) in the seed, which digests its food just as truly as the fluids of our stomach digest ours. Here, then, are digestion, absorption, and assimilation going on in the seed as it begins to grow. If the food stuffs in the seed were not stored in a dry and insoluble form, they would dissolve and decay. It is necessary, therefore, if a seed is to keep over winter, that its food must be both dry and insoluble.

Examples of Seed Structure

Each seed differs somewhat from the general description just given; the parts of the embryo may be well or poorly developed; the number of cotyledons may vary; and the endosperm may be large or lacking altogether.

All that is necessary for a true seed is the embryo, stored food, and protective coverings. These are often very different in structure, to adapt them to various surroundings.

The bean is presented as an example of a dicotyledonous seed without endosperm, while the corn is taken as a type of a monocotyledonous seed in which there is a very large endosperm.

The Bean. External Structure. This familiar seed is usually kidney-shaped or oval in outline, several being borne in a pod, which is the true fruit of the plant.

The testa is usually smooth and may be variously colored; on the concave side it bears a scar (hilum), marking where it

was attached to the pod. By means of this attachment it received nourishment when growing on the parent plant.

Near the hilum is a tiny opening (micropyle). Toward this there sometimes extends a ridge showing the location of the hypocotyl, which will emerge here on germination. The tegumen is very thin and often cannot be separated from the testa.

The Bean. Internal Structure. On removing the seed coats, the kernel is seen to consist of the embryo only, the endosperm having been completely absorbed. All the nourishment is now stored in the cotyledons which are large, not at all leaf-like, and contain much protein and starch.

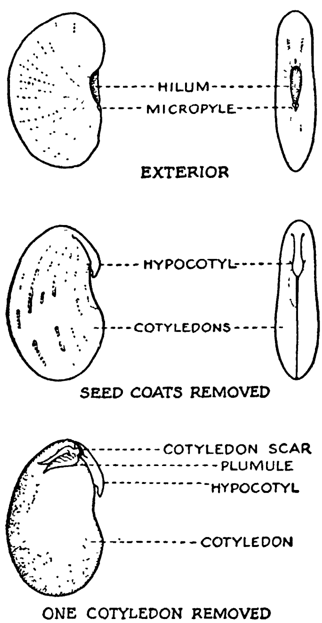

Fig. 5. Structure of the bean.

The hypocotyl is seen as a finger-like projection, fitting into a protective pocket in the seed coats. To it the cotyledons are attached on either side.

By removing one "half" (cotyledon) of the bean, the plumule is exposed, attached to the hypocotyl above the cotyledons and closely packed in between their ends. It is fairly well developed and can be seen to consist of two small leaves, with well-marked veins, folded over each other.

It will be noted that the upper end of the hypocotyl is the one point where all three parts of the embryo are united. When the cotyledon is removed, a scar showing its place of attachment is left on the side of the hypocotyl.

Corn. External Structure. The corn "seed," as it is usually called, is really a *fruit* corresponding to the bean pod, rather than to the bean itself. One seed completely fills the fruit, so that the seed coats and fruit coats cannot easily be distinguished in the grain of corn.

As a result of this fact, the hilum and micropyle are covered by the fruit coats and what might be mistaken for the hilum is really the point of attachment of the corn fruit (grain) to the cob.

On one side of each grain can be seen a light-colored, oval area, which marks the location of the embryo, visible beneath the coats. On the same side, but at the end opposite the point of attachment, is located a tiny point, the silk scar, where the corn "silk" formerly grew.

Corn. Internal Structure. Internally the corn consists of a large endosperm, containing much starch, protein, and some oil, and at one side near the point of the grain, a much smaller part, the embryo.

This embryo has but one *cotyledon*, a rather irregular, oval structure, wrapped around the plumule and hypocotyl, and lying in close contact with the endosperm. Its function is to digest and transmit to the growing seedling the food stored in the endosperm. It is a real digestive organ, which makes the food soluble, just as truly as does an animal's stomach or intestine.

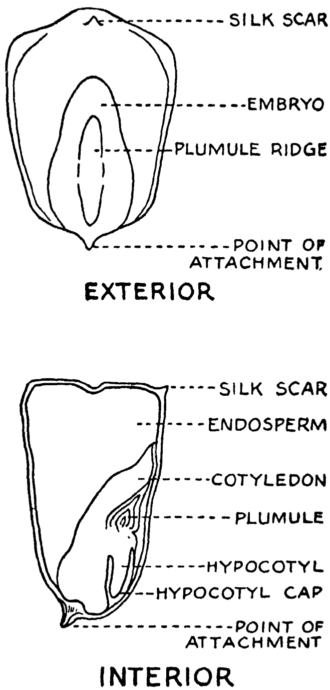

FIG. 6. Structure of coı

The *hypocotyl* of the corn is a small pointed organ, aimed toward the attached end of the grain, thus lead the *micropyle* to be in that region. It is c which protects it as it passes through the begins to develop.

The *plumule* is also protected by a sh sists of several very small leaves ro'

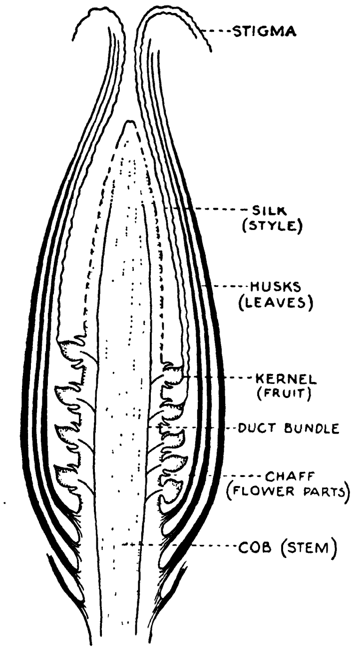

FIG. 7. Structure of the "ear" of corn. This is really a spike of fruits (kernels), closely grown together and enclosed in the husks.

compact "spear" which can safely push upward through the earth.

The cob, on which the kernels are borne, is really a stem of the spike of flowers, each of which produces one kernel. The corn ear is a spike of fruits, closely grown together, and not a single fruit like a bean pod. The chaff around the grains represents some of the outer flower parts. The silk is a portion of the central organ of the flower called the pistil, and its function is to catch and transmit the pollen grains. This will be explained in the chapter on fertilization. The husks are modified leaves developed to protect the corn ear.

Bean	*Corn*
Has testa with hilum, and micropyle plainly visible	Hilum, etc., covered by fruit coats
Two cotyledons	One cotyledon
Large embryo	Small embryo
No endosperm	Large endosperm
Plumule fairly large	Plumule rather small
le leaves folded	Plumule leaves rolled
pod, with many	The fruit a single grain, with one seed

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SUMMARY OF CHAPTER VI

SEEDS

1. Definition of seed.

A plant organ whose function is to reproduce the plant, consisting of:
- a. The living miniature plant (embryo).
- b. Stored food.
- c. Protective coverings.

2. Structure of seeds.

- a. Coats. Function, Protection.
  - (1) Testa (outer coat).
    - Hilum (scar on testa). Point of attachment for supply of nourishment.
    - Micropyle (opening). Entrance of pollen, exit of hypocotyl.
  - (2) Tegumen (inner coat).
- b. Kernel.
  - (1) Embryo (miniature plant, always present).
    - (a) Cotyledons (seed leaves).
      - Development.
        1. Leaf-like (squash).
        2. Store food, but come up (bean).
        3. Store food below ground (pea).
        4. Digest and absorb from endosperm (corn).
      - Number.
        1. Monocotyledonous (one cotyledon) (corn).
        2. Dicotyledonous (two cotyledons) (bean).
        3. Polycotyledonous (several) (pine).
    - (b) Plumule (undeveloped shoot).
      1. Small if much stored food.
      2. Large if little stored food.
    - (c) Hypocotyl (part below cotyledons).
      1. Root from lower end.
      2. Raises cotyledons if it grows *up*.
  - (2) Endosperm (stored food, may be lacking).
    1. Why not always present?
    2. Use to man.

3. Food in seeds.

- a. May be stored in cotyledons or endosperm.
- b. Why stored dry and nearly insoluble.
- c. Need of digestion, use of diastase.

4. Types of seed structure.

- a. Bean (dicotyledonous, no endosperm). The pod is the fruit.

(1) External structure.
  (a) Shape, color, etc.
  (b) Testa.
    1. Hilum, caused by attachment to pod, used to receive nourishment from plant.
    2. Micropyle, used for exit of hypocotyl (see ridge), used for ingress of pollen (see fertilization).
  (c) Tegumen (thin, unimportant).

(2) Internal structure. (Embryo occupies whole seed.)
  (a) Cotyledons.
    a. Two.
    b. Large and rather thick.
    c. Contain starch and protein.
  (b) Hypocotyl.
    a. Finger-shaped.
    b. In protective pocket.
  (c) Plumule.
    a. Moderately developed.
    b. Two plain leaves.
    c. Veins, etc.
  (d) No endosperm. (What has become of it?)

b. Corn ("Kernel" is the true fruit).

(1) External structure.
  (a) Point of attachment to cob (at narrow end).
  (b) Embryo mark on side.
  (c) Silk scar at broad end.
  (d) Hilum and micropyle covered by fruit coats.

(2) Internal structure.
  (a) Endosperm. (Large—much stored starch, protein, oil.)
  (b) Embryo.
    1. Cotyledon.
      a. One.
      b. Oval.
      c. Against the endosperm.
      d. Used to digest and transmit food.
    2. Hypocotyl.
      a. Protective cap.
      b. Points to attached end of seed.
    3. Plumule.
      a. Protective cap.
      b. Rolled leaves.
      c. Adapted for piercing soil.

(3) Structure of ear of corn.
  (a) Cob (the stem of flower spike).
  (b) Chaff (outer flower parts).
  (c) Kernel (the fruit).
  (d) Silk (the pistil for catching pollen).
  (e) Husks (leaves for protection).

CHAPTER VII

GERMINATION—THE SEED WAKES UP

Vocabulary

Dispersal, the act of scattering, as of seeds.
Emergence, coming out of anything.
Penetration, forcing a way through.

The seed is not a thing totally distinct from the parent plant, though it is separated from it. It contains the same protoplasm as the parent plant, with this distinction; its protoplasm is in a condition of rest. The seed is not dead, it is asleep and waits only for favorable conditions to wake into the activity of growth.

Function of the Seed. This resting stage is of two-fold value —it condenses the essential nature of the whole plant within small compass, capable of easy and wide dispersal, and, most important of all, protects the vitality of the embryo so that the seed can withstand periods of drought, cold, heat, or other conditions which would be fatal to the parent plant.

Both dispersal and preservation are steps toward the chief function of the seed, which is to reproduce the plant that is at rest within it. This resumption of active life is called *germination.*

Necessary Conditions for Germination. For the germination of most seeds at least three conditions are required, in amounts varying between wide but definite limits; these are moisture, heat, and air.

There are a few plants whose seed will develop under water while others retain enough of the scant dews of the desert nights to waken the seed into growth. Usually, however, a moderate water supply is essential, too much causing decay, and too little preventing growth altogether.

As to temperature, a maple seedling will germinate on a cake of ice and many other seeds grow in extreme cold, while a smaller

number bear high temperatures. The majority, however, germinate most freely between 60° and 80° F.

Air from some source is essential to growth, for seeds, like all living things, must breathe. Many can obtain the needed supply even from the air dissolved in the water in which they may be submerged.

In addition to these external conditions, the embryo must also have a supply of stored food for immediate use while the roots

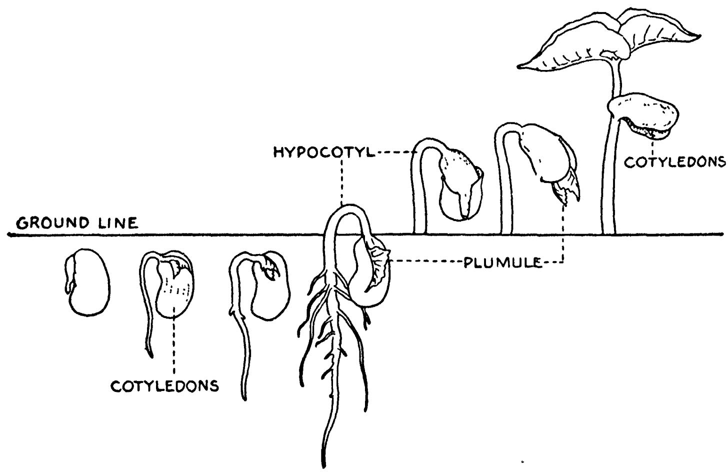

Fig. 8. Stages in the germination of the bean. The second, third, and fourth stages are drawn with one cotyledon removed to show the growing plumule.

and leaves are developing. This food may be stored in the cotyledons, as in the bean and pea, or outside the embryo, as in the case of the endosperm of the corn and other grains.

Stages in Germination. Germination consists of three steps; emergence from the seed coats, penetration of the soil, and the obtaining of first nourishment.

In getting out of the seed coats, the hypocotyl appears first, emerging by way of the micropyle. The rest of the embryo follows by various ingenious schemes, all apparently planned by Nature to enable the seedling to escape uninjured from the testa, on whose protection it has so long depended.

Penetration of the soil may be either from above or from below. When seeds are scattered on the surface of the soil they are enabled to gain a foothold in the earth by various contrivances so that the roots may be sent down into the soil. In the case of buried (planted) seed the process of penetration not only has to do with sending down roots, but the plant must find a way out of the earth, unharmed by its passage. This latter problem is solved most often by the plantlet being started from the seed in an arched position. One end of the arched stem takes hold of the ground and sends out roots, while the other, attached to the wide cotyledons or the delicate plumule leaves, gently pulls these through the ground after the growing arch has broken a way to the surface. If forced directly upward these appendages would be stripped off by soil pressure.

This arch may be caused by the weight of the cotyledons and soil (as in the case of the bean), which hold back the bulky end of the plantlet until the stem is strong enough to lift it out of the ground, or (as in the case of the pea) by the tip of the plumule being held tightly between cotyledons that are not lifted from the ground at all. In the latter case the hold of the cotyledons weakens after their store of food has been partly exhausted and the plumule is released.

Another method of penetrating the soil is found in the corn and in general by those plants whose first leaves are long and slender. In these cases protection is secured by the leaves being tightly rolled into a point and covered by a cap, so that they pierce the soil directly, thus meeting less resistance and securing safety.

The lifting force of germinating seeds is seldom noticed, but is very great. Masses of earth many times their weight are lifted by our tiny garden seedlings as they come up, forcing their way through the hardest soil.

The last and most important step in germination is the establishment of the young plant in its new environment. In describing this process it is necessary to deal with the development of each part of the embryo by itself. The hypocotyl first penetrates the testa. Protected by its root cap, and

directed downward by gravitation, it begins at once the production of the primary root from its lower end. From this, in turn, the whole root system rapidly develops. The region of growth is just back of the tip, which, protected by the cap, is safely pushed downward into the earth.

The cotyledons, as before explained, may rise above ground if the hypocotyl lengthens upward, or, if not, may remain below. In either case they act as a source of food for the seedling.

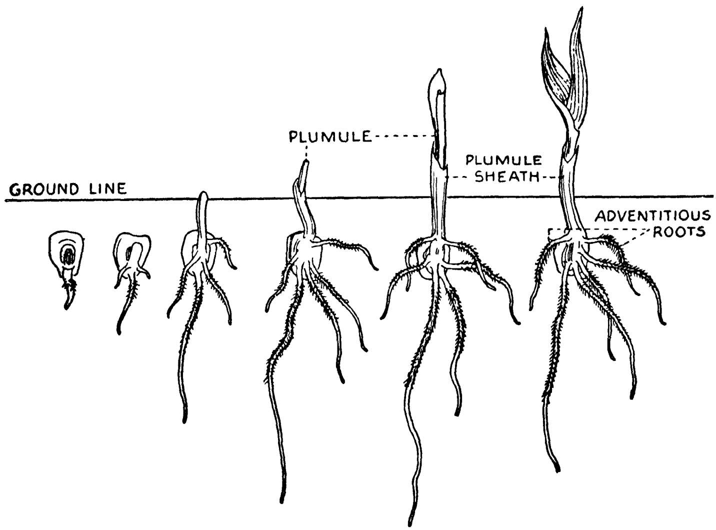

FIG. 9. Stages in germination of corn.

The development of the plumule usually attracts most attention for from it arise the leaves, stem, and, later, the flowers and fruit. It constitutes the shoot of the plant.

The first organ to develop in germination is the root, because the function first required by the seedling is absorption which the root performs. We shall take up the study of this important organ in the next chapter.

Kinds and Uses of Stored Food. Many of the statements made in this and the preceding chapter, can be proven by simple experiments. In the first place, the kind of foods

stored in the seeds can be proven by the tests described in Chapter IV. The necessity of this stored food can be shown by taking a number of well-started seedlings, removing part of the stored food (in cotyledon or endosperm) in some of them, removing it all in others, and leaving still others unharmed. If these seedlings are then placed so that the root can dip into water, by suspending them on a netting over a well-filled glass, their development can be watched.

Several seedlings must be used in each group, lest we draw conclusions from too few instances, or perhaps be misled in case some one seed is abnormal. The conditions of growth must be the same in each case, lest it appear that these varying conditions, and not the loss of stored food, produce the results.

After a few days it will be seen that the whole seeds grow well and rapidly; that those with part of their food removed start more slowly and soon cease growing; while those with all the stored food removed scarcely start at all. This is because of the fact that, until the seedling can develop roots and leaves, it depends solely on this store of food whose removal is shown to have so serious results.

The Digestion of Stored Foods in Seeds. To prove that these food stuffs must be digested before they can be used in germinating plants, corn seeds can be tested for starch and for grape sugar, both before and after germination has started.

Starch is insoluble in cold water, and does not pass readily through the absorbing membranes. Therefore it has to be digested (changed to soluble sugars) before the plant can use it. This digestive change is accomplished by a substance in the seed, called diastase, which acts somewhat like the digestive fluids in our bodies.

If the corn be tested before germination has begun, much starch and little or no sugar will be found. If it be tested in the same ways, after germination has proceeded for a few days, the reverse will be discovered, as most of the stored starch will have been coverted into soluble form, sugar, by the diastase in the cotyledon.

Conditions for Germination. That sufficient heat, air, and moisture are essential conditions for germination, can be proved by setting up experiments in which several seeds are given similar treatment, except that one of these factors is changed in each case.

To prove the necessity of air, place several seeds in each of two bottles, give them moist moss to grow in, and keep in places of similar temperature. Seal one tightly and leave the other open. The results show that the sealed seeds, though they start growth, cease to grow as soon as the air in the bottle is used up, while those in the open bottle grow naturally. In this, as in all experiments, several seeds should be used, so as to prevent drawing a false conclusion from incomplete evidence. Using many seeds and repeating the same experiment increases the accuracy of the test. Emphasis must also be placed upon giving the *same conditions*, with the one exception, in every case. In the above experiment, if the seeds are not kept in places of similar temperature and moisture, the result of the experiment might be attributed to the differences in these factors and not to the presence or absence of air.

In the same way, it can be proved that seeds require a definite amount of moisture for germination. If none be supplied, or if they be completely covered with water, most seeds will not grow even when the air supply and temperature are properly regulated.

A similar experiment may be used to show the effect of temperature on seed growth. Arrange several seeds in each of three or four bottles; give the same amount of moist moss to grow in, and expose all to free air supply. The one condition to be varied is the temperature, which may be done by putting each bottle in a place of different heat or cold. It will be found that those in extreme cold usually do not start growth at all, those in very warm places usually decay, and only those in a moderate temperature germinate naturally.

Suppose some of these last sets of seeds had been given varying amounts of moisture as well as different temperatures, what objection could be raised to the conclusion given?

Experiments like those above in which no air or water or warmth were supplied and in which no results occurred are sometimes called "check" experiments. They are very important, as showing that a certain result will *not* occur without certain conditions, which is often as necessary as proving that it *will* occur with certain others.

Heat Energy and Carbon Dioxide Set Free. It has been stated in Chapter II that all living things *breathe.* This means that they take in oxygen, which oxidizes their tissues, produces heat, and liberates carbon dioxide as a waste product. We readily realize this in the case of animals but with plants it needs experimental proof.

Provide two large-mouthed bottles each with some moist moss, a vial of limewater, and a stopper through which is inserted an accurate thermometer. In one of them put a handful of soaked seeds and leave the other with none.

As the seeds begin to grow it will be observed that the thermometer in that bottle stands higher than in the one with no seeds, also that the limewater in the seed bottle is *much more milky,* which proves the presence of more carbon dioxide. The limewater in the seedless bottle is *slightly* milky due to the carbon dioxide present in the air. Without this check experiment, nothing could be proved, as the rise of temperature could not be compared and the presence of the carbon dioxide could be attributed to that known to be in the air. Moss was put in both bottles so that all conditions should be the same; if this had not been done, it might have been objected that the presence of the wet moss affected the temperature or gave off carbon dioxide.

While plants do not breathe as actively as animals, still it is thus proved that they do breathe *in the same way* and for the same purpose, namely, to liberate energy for life. The fact that they are less active, and need less energy accounts for the fact that evidence of their breathing is less noticeable.

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SUMMARY OF CHAPTER VII

GERMINATION

1. Functions of Seed.
- a. Reproduction.
- b. Dispersal.
- c. Protection for winter.

2. Conditions for Germination.
- a. Moisture.
- b. Air supply.
- c. Moderate temperature.
- d. Stored food.

3. Stages in Germination.
- a. Emergence from seed coats.
  - (1) Adaptations.
    - (a) Micropyle.
    - (b) Cap on hypocotyl.
- b. Penetration of soil.
  - (1) By arching caused by.
    - (a) Soil pressure (bean)
    - (b) Cotyledon pressure (pea).
  - (2) By direct piercing aided by.
    - (a) Rolled plumule.
    - (b) Plumule sheath.
- c. Obtaining nourishment.
  - (1) From food stored in cotyledons (bean, pea).
  - (2) From food stored in the endosperm (corn).
  - (3) From food made in leaf-like cotyledons (squash).
  - (4) Later from food obtained by roots and plumule leaves.

4. Experiments to show.
- a. The kind of food stuffs stored in seeds.
- b. Necessity for stored food.
- c. Necessity of digestion of stored food.
- d. Necessity of air, warmth and moisture for germination.
- e. That growing seedlings produce carbon dioxide in respiration.

CHAPTER VIII

ROOTS—THEIR STRUCTURE AND FUNCTION

Vocabulary

Adventitious, growing at unusual places.
Epidermis, the outer layer of plant or animal tissues.
Cortex, a spongy layer under the epidermis of roots.
Cambium, region of active growth in root or stem.

The developing seedling consists primarily of the root and the shoot. The latter bears the buds, leaves, flowers, and fruit, while the root, usually hidden and unnoticed in the soil, plays an equally important part by furnishing food materials and support to the plant.

Characteristics of Roots. The root differs from the stem in the following points:

Root	*Stem*
Bears no leaves or flowers.	Bears leaves and flowers.
Grows irregularly.	Grows by definite nodes.
Growth mostly at tip.	Growth in each internode.
Tip protected by cap.	Tip protected by scales.
Branching very irregular.	Branching regular.
Turns toward the earth.	Turns away from the earth.

Root System. When a plant is pulled from the soil, the root system is exposed. This may consist of one long central portion, the primary root, from which many secondary branches grow; or it may be a fibrous mass of small roots with no apparent primary, as in most grasses. In either case the soil particles are closely held to the root by tiny root hairs, the active agents in absorption which are adapted to take up the thin film of water that surrounds all soil particles.

While the form of the root system varies greatly, according to the kind of plant, soil, and climate, yet, in general, all roots have a very similar internal structure, as is shown by a study of sections of roots in the laboratory. The tips of young roots,

split lengthwise and dyed, so as to make their structure plain, should be used for the purpose.

Internal Structure. A typical root has a single outer layer, the *epidermis,* composed of thin-walled, brick-shaped cells, from which extend innumerable outgrowths called root hairs. Beneath the epidermis is a thicker layer of thin-walled, loosely packed, roundish cells, the *cortex.* This is separated by a boundary layer from the central cylinder which occupies the remainder of the root. In this central cylinder there are three sorts of tissues which are also found in stems, though differently arranged. They are: (1) wood and ducts, (2) bast, (3) cambium.

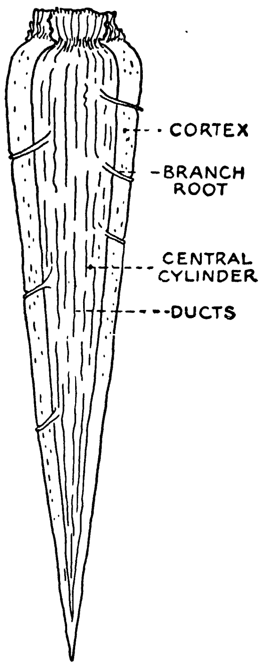

FIG. 10. General structure of a fleshy root. (Carrot). Adapted for food storage.

The woody tissue is composed of thick-walled, hard cells which give strength to the root but carry little sap, and ducts, which are long, tubular cells, used principally for the transfer of sap upwards toward the stem. The bast tissue consists of tough, fibrous cells, interspersed with tubular ones. Its function is both to give toughness and to carry sap downwards. The cambium is the most remarkable tissue in the plant. It consists of thin-walled, very active cells, full of living protoplasm which have the power of rapid growth. In fact, all growth of the plant occurs here, and if the cambium be destroyed, the plant will die.

Since these tissues extend into the stem, where we will hear of them again when we study stem structure, it is important that we should remember their function in the root.

The wood and ducts are generally grouped in four areas near the center, and alternating with them, though outside, is found

the bast. The cambium forms a more or less complete ring between the two. This arrangement permits the soil water to reach the ducts without mixing with the digested food brought down from the leaves by the bast.

Around the tip of each growing root and extending up a little way along each side is the protective root cap, composed of

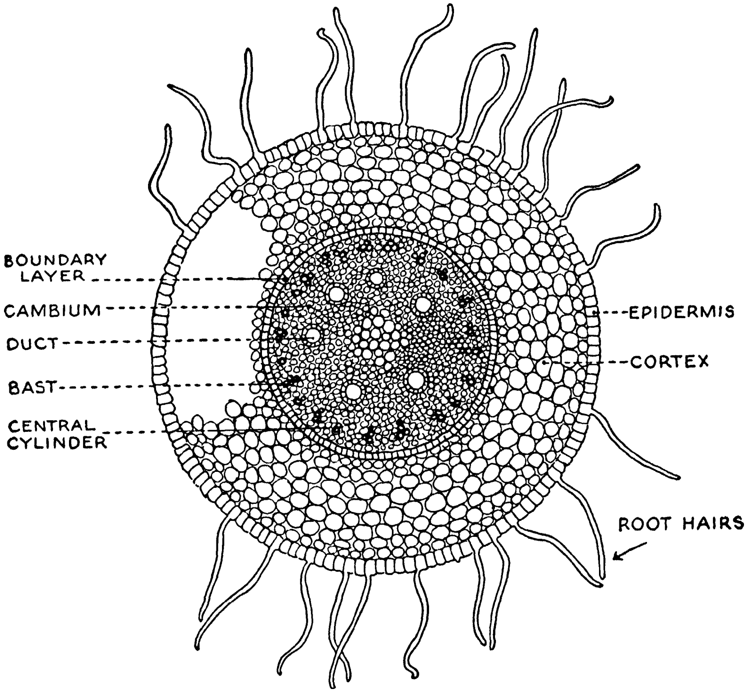

FIG. 11. Cross section of root. Note the root hairs formed from the cells of the epidermis. From Atkinson.

loose cells easily rubbed off without allowing injury to the sensitive tip as it pushes through the soil. The region of most active growth, being back of this cap, is protected from injury, as would not be the case if located at the extreme tip.

Function of Root Parts. The function of the epidermis and its root hairs is mainly absorptive. The cortex absorbs, retains, and transfers the soil water; the ducts and bast tubes transfer

liquids and air, while fibers in both bast and wood give toughness and strength. The most important function, however, is performed by the cambium, which is the region of active growth, and from which both wood and bast are produced.

Functions of Roots as a Whole. *Absorption.* The root, as is evident from its structure, is primarily an absorbing organ. This function will be taken up at length. However, it has many other uses and is adapted to perform very different duties in different plants.

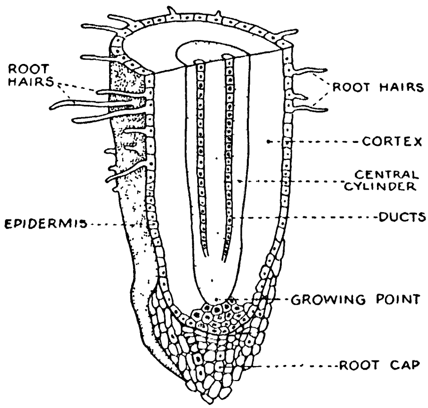

FIG. 12. Diagram showing the minute structure of a root at the tip.—This shows the extreme tip, highly magnified. The separate cells show plainly, and those near the growing points are particularly full of protoplasm and have large nuclei, showing that they are in active growth.

The loose cells of the cap have few nuclei and are largely dead cells, thrown off as protection to the delicate tip.

The ducts begin to show as thicker rows of cells though not very tubular at this stage.

The epidermis shows plainly as a single layer of cells packed in like bricks. Root hairs are shown as outgrowths of epidermal cells.

Fixation. A second use, common to nearly all roots, is that of attaching the plant to the soil, and holding it in an upright position.

Storage. Frequently the root has sufficient bulk to act as a very efficient storage place for foods. This is particularly important for plants that retain life through long winter months.

Propagation. It may happen that enough nourishment is stored so that the plant can send up shoots at various places or even be divided, so reproducing the plant.

Adaptations of Root Form. From the foregoing it is evident that roots must be profoundly varied in structure and form to perform the different functions mentioned. And it must be remembered that not only function, but other factors such as

climate, soil, moisture, and exposure, which together make up the plant's environment, affect growth. We shall learn that only so far as a plant is fitted to its environment will it thrive.

Kinds of Roots. The usual place from which roots develop is the lower end of the hypocotyl. Such roots are called *normal roots*. If they grow from other places such as the stem, leaves, or upper part of the hypocotyl, they are called *adventitious roots*.

Normal Roots

Soil Roots. Of all forms of normal roots, the commonest are the soil roots. These are of many kinds, depending upon what functions they must perform and the character of the soil, moisture, or climate that surrounds them. They in turn may be divided into three general classes.

Fibrous Roots are made up of many fine slender rootlets, giving large extent of surface for absorption. The roots of the grasses, for instance, are so numerous that they hold the soil together, forming a compact layer called the "turf."

Tap Roots are greatly lengthened primary roots which enable the plant to go deep after water supply and hold firmly in the ground. The thistle, dandelion, burdock, and many more of our worst weeds are thus adapted to make a living under adverse circumstances.

Fleshy Roots are adapted for storage of food stuffs and have the main part thickened, as in the carrot, turnip, and beet. They are generally found in plants which require two seasons to mature their seed and so need stored food to carry them over the winter. In other cases, as the dahlia and sweet potato, the fleshy root is used to reproduce the plant.

Aerial Roots. Some tropical orchids which live attached to trees and never reach the earth at all develop aerial roots. They have a very thick, spongy cortex, which absorbs water from the moist air of the forests.

Aquatic Roots. These are found in a few floating plants such as the duck-weed and water hyacinth. They are usually small,

few in number, and lacking in root hairs. They do not need extra surface for absorption because they are surrounded by an abundant water supply.

Adventitious Roots

Brace Roots. From the stems of corn and many other grasses, develop brace roots, which help to support the slender stems or to raise them again if they are bent down.

Roots for Propagation. In certain plants if the stem lies in contact with the soil for a sufficient length of time, roots will spring from the joints and produce new plants. The stems of various berry bushes can thus be fastened to the earth—"staked down"—and will take root in this way. The new root systems, when sufficiently developed, can be separated from the parent plant to make a new berry bush.

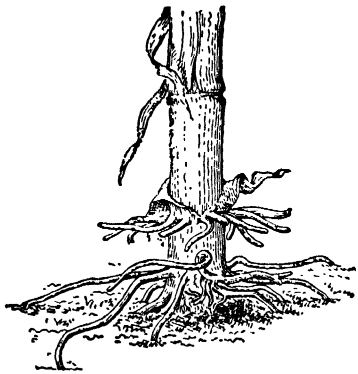

Fig. 13. Bracing roots of Indian Corn.

Slips or cuttings from certain plants develop adventitious roots from the stem or leaves and start new plants by this means. Many plants, like the strawberry, send out horizontal stems called "runners" from which adventitious roots develop and produce other individuals.

Climbing Roots. The stems of poison ivy, trumpet creeper, and some other vines grow climbing roots which act chiefly as means of support. These plants have ordinary soil roots, also, for the purpose of absorption.

Parasitic Roots. In a few plants, such as the dodder and mistletoe, parasitic roots develop from the stem, penetrate into the tissue of some other plant, and absorb food from their victim, often causing its death or serious injury. The dodder is parasitic upon clover, golden-rod, and other plants; the mistletoe usually grows upon the oak.

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SUMMARY OF CHAPTER VIII

ROOTS

1. Characteristics.
- a. No leaves or flowers.
- b. Growth back of tip, not at nodes.
- c. Root cap for protection, instead of bud scales.
- d. Irregular branching.
- e. Turn towards gravity, against light.

2. Root system.
- a. Primary root or fibrous roots.
- b. Secondary roots.
- c. Root hairs.

3. Internal structure.

Part	Structure	Function
a. Epidermis	Thin, brick shape	Protection
Root hairs	Thin, tubular, sensitive	Absorption
b. Cortex	Loose, thin, round	Transfer Storage
c. Central cylinder		
Wood	Thick, fibrous	Support
Ducts	Thick, tubular	Transport
Bast	Thin, tubular	Transport
Cambium.	Delicate, active	Growth
d. Root cap	Loose, thin cells	Protection

4. Functions.
- a. Absorption (most roots).
- b. Fixation in soil (most roots).
- c. Storage (carrot, etc.).
- d. Propagation (hop, dahlia, etc.).

5. Modifications.

a. Causes.
(1) Difference in function.
(2) " " climate.
(3) " " soil.
(4) " " moisture.
(5) " " general surroundings.
(6) " " exposure.

6. Kinds

a. Normal forms	Examples	Adapted for
1. Soil Roots		
(*a*) Fibrous	Grass	Wide surface
(*b*) Tap-root	Dandelion	Deep water supply
(*c*) Fleshy	Carrot	Storage
2. Aerial	Orchid	Absorption from air
3. Aquatic	Duck-weed	Absorption from water
b. Adventitious lorms		
1. Brace-roots	Corn	Support
2. Propagation	Strawberry	Reproduction
3. Climbing roots	Poison-ivy	Support, climbing
4. Parasitic	Dodder	Stealing nourishment

7. Adaptations.

a. For penetration of soil.
(1) Protective cap.
(2) Growing point back of tip, for protection.
(3) Root hairs back of tip, for protection.
(4) Geotropism and hydrotropism (see next chapter).

b. For storage.
(1) Large size.
(2) Protection in soil from cold, drought, and animals.
(3) Poisonous or bad tasting, to protect from animals.

c. For support.
(1) Depth and extent of root system.
(2) Toughness of wood and bast fibers.
(3) Special brace roots, climbing roots, etc.

Note: Look up cypress "knees," and adventitious roots of banyan tree.

CHAPTER IX

ABSORPTION AND OSMOSIS

Vocabulary

Hydrotropism, the response of plant parts to water.
Geotropism, the response of plant parts to gravitation.
Osmosis, the diffusion of two liquids or gases through a membrane, the greater flow being toward the denser substance.
Turgescence, the support of plant parts, especially leaves, due to the presence of water in the tissues.

The preceding chapter has given us a rather definite idea as to the structure of roots, and the names, at least, of some of their functions. This chapter deals with absorption, the most important function of all, since it is one of the principal ways in which plants obtain food materials. We shall study in detail the adaptations of the root for this fundamental function.

Necessity of Water for Plants. All living matter depends more or less on liquids of various sorts, and the plant, like the animal, has its circulating fluids, bearing nourishment and removing waste, storing food, and supplying oxygen to convert that food into living energy.

From the delicious juices that flavor the peach and sweeten in the heart of the sugar cane, to the bitter milk that flows in the dandelion or lures the unwary to death in the poisonous mushroom, all consist largely of water, absorbed from the soil by the action of the roots.

This absorbed water is of threefold value to the plant. It supplies a very necessary portion of the plant's food, as water itself and as mineral matter dissolved in that water; it acts as a means of transfer within the plant for the various foods needed in the different parts, much like the blood of animals; and it supports many parts of the plant. This latter statement will need some explanation.

Turgescence. When a plant is deprived of water, its leaves droop and we say it wilts. This is due to the fact that, normally, each cell is expanded by the water within it and so is kept in position. If the water be withdrawn, these cells will collapse somewhat like an empty balloon, allowing the leaves and plant to droop. If water be supplied before the protoplasm dies, the leaves and plant may resume position.

This stiffness of plants, due to presence of water, is called *turgescence* and is very important in supporting the smaller plants whose stems are not stiffened with wood fibers. Nearly all leaves depend to a considerable degree on this water pressure for their expansion. The water to supply these absolutely essential needs comes from the soil, often apparently dry, but always containing at least a little moisture which the plant must obtain if it is to live.

Osmosis. This vastly important root function of absorption depends on a physical process called *osmosis* which may be defined as the mixing or diffusion of two liquids or gases of different densities through a membrane—the greater flow being toward the denser substance.

Diffusion is the mixing of liquids or gases which takes place without their being stirred. Open a bottle of perfume and you can soon smell it in all parts of the room, even though the air has not been disturbed. Put a lump of sugar in a glass of water; it dissolves and can soon be tasted in all parts of the water without any stirring of the liquid.

Fluids (liquids or gases) tend to diffuse in this way making a mixture that is alike throughout. Heavy substances diffuse more slowly than lighter ones. Substances which do not dissolve in a given liquid naturally do not diffuse through it.

Diffusion will go on through some kinds of membranes. This process of diffusion through a membrane is *osmosis.* Most of the membranes of living things permit osmosis to go on, especially those concerned with taking in water, food, and oxygen, and in excreting waste. Artificial osmotic membranes can also be made.

Most osmotic membranes have the property of letting water

pass through more readily than dissolved substances: the less dense fluid flows through faster than the denser one. Such a membrane, more easily penetrated by one substance than another, is called a *semi-permeable* membrane. In living tissues the layer of protoplasm which lines each cell wall and sometimes the cell wall itself is such a membrane.

Osmosis is one of the most important biologic processes. Upon it depends, at least in part, not only absorption in roots,

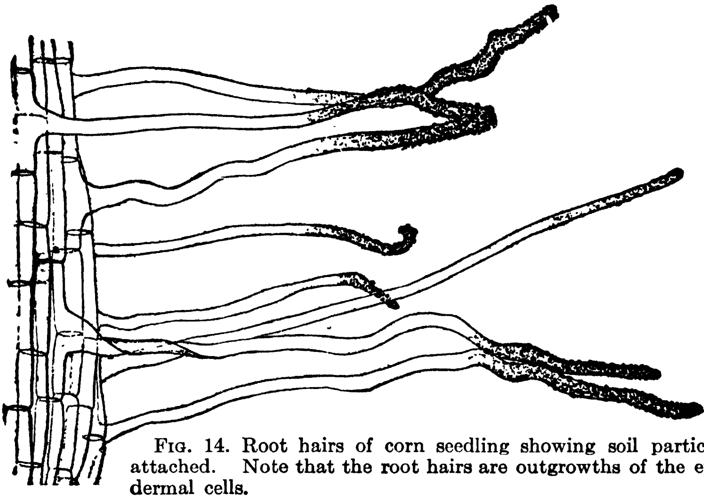


FIG. 14. Root hairs of corn seedling showing soil particles attached. Note that the root hairs are outgrowths of the epidermal cells.

but all forms of absorption in plant and animal, all digestive processes, excretion, respiration, and assimilation. Wherever a liquid or gas passes through any tissue, osmosis is usually the acting cause, controlled by the living protoplasm that lines the cell. The essentials for osmosis in roots are a dense liquid, a less dense liquid, and the osmotic membrane. In the root the protoplasmic layer lining the walls of the root hairs acts as the membrane, the cell sap as the denser and the soil water as the less dense liquid.

Root Hairs. It has been estimated that there may be a total length of a mile in the roots of a corn plant, and alfalfa roots have been found to extend twenty feet deep in dry soil. The surface of the active parts of all roots is covered with root

hairs. These are outgrowths of the epidermal cell walls and increase the total absorbing surface enormously. They also enable the osmotic membrane almost to touch the film of water, which, even in the driest soils, clings to the soil grains.

So important are these root hairs that their injury or loss might mean death to the plant, hence they are never borne at the extreme tip of the root, where its growth through the soil would strip them off, but are found a little back from the tip and extending various distances along the younger roots.

As the root grows, new hairs are produced near the tip, to gather moisture from new areas; the upper ones die away; the cortex and epidermis thicken, cease active absorption, and become protective in use. In frequent cases, the root hairs secrete a weak acid which helps in dissolving soil substances and in penetrating hard earth.

The adaptations of root hairs may be summarized as follows:

Extent of surface.	Thinness of walls.
Protection from injury.	Location.
Close contact with soil rains	Acid secretion.

Geotropism. In order that roots may always grow where they can best absorb food materials, they usually show a tendency to grow downward, *i. e.*, toward the earth. This might at first thought be credited to mere weight, but it is evident that stems, though equally heavy, cannot be made to grow down, and that roots, though lighter than the soil, still force their way through it, and cannot be made to grow upward, even though repeatedly started in that direction.

This turning of roots and stems is caused by the attraction of the earth, called gravitation, and this response that plants make to gravitation is called *geotropism*—positive in the case of roots, and negative in the case of stems. Positive geotropism plays an essential part in absorption by causing the roots to penetrate the soil rather than grow in any chance direction.

Hydrotropism. Roots respond similarly to the presence of water, turning toward moisture even at long distances. This tendency, called *hydrotropism*, is very useful, especially if soil

water be scant. Vast numbers of fine roots are often found projecting into springs and streams, forcing their way into water pipes or piercing deep into the soil, led by this force that turns them toward the needed moisture.

The roots of poplar trees so frequently penetrate into drain pipes that in many cities the planting of poplar trees on the streets is forbidden.

Selective Absorption. Another fact connected with absorption is, that plants, though growing side by side, take very different matters from the same soil. This apparent impossibility is accomplished by the action of the protoplasm which lines the inner walls of all active cells and has the remarkable power to select, in a considerable degree, what substances the roots shall absorb with the water. This selective absorption, as it is called, accounts for the variety of food substances taken from the same soil by different plants.

Successive Osmosis. All this arrangement for absorption would be useless, were there not some way provided for passing on the absorbed liquids after being taken up by the root hairs. When the outer layer of cells has taken in soil water their contents are diluted, and they become less dense than those next within. Their contents tend to pass to the next inner layer, as the osmotic current is always toward the denser liquid.

This last step removes the newly absorbed soil water from the epidermal cells and leaves them denser again, ready to absorb more soil water from without.

Root Pressure. This process continues inward, from cell to cell, till the ducts are reached, when the liquids rise up through root and stem, causing the uplift which is known as root pressure.

This root pressure is one important cause of the circulation of sap in plants, and is often sufficient to raise the water to heights of one hundred feet or more. But neither this nor any other known cause is equal to the task of lifting water as high as some of our tallest trees, and the method by which that is done is still unknown. This inward osmosis may be reversed by putting salt in the soil. It dissolves in the soil water and makes it

denser than the contents of the cells. Therefore the cells are robbed of their water since the osmotic flow is toward the liquid of greater density. This fact is often utilized in killing weeds and grass along the sidewalks.

Variations in Osmosis. Osmosis in roots is affected by the temperature and amount of moisture in the soil, being less in cold, dry seasons. Also the presence of organic acid in bogs, or of certain mineral matters in some soils, tends to hinder or prevent the process. Hence in our cold season, most plants shed their leaves, so that they have less surface from which to evaporate water, because their supply is cut down by the cold.

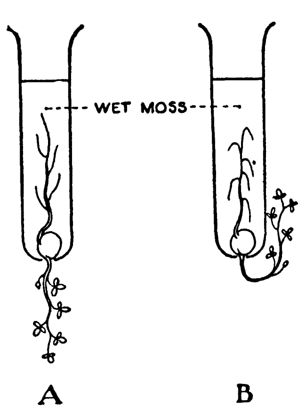


FIG. 15. An experiment to show geotropism. Shown at A as first set up, with roots pointing upward and stem downward. After two days the positions shown at B will be evident. The roots now bend down and the stem turns upward.

In the case of both bog and desert plants, many schemes to retain moisture have developed. Though in such different surroundings, both classes of plants have difficulty in absorbing enough water, because of the stoppage of osmosis.

Aerial roots find even greater difficulty in obtaining sufficient water, and many wonderful devices have been developed in the way of hairs to radiate heat, scales to catch water, and enormous, thickened cortex to retain it when once it is absorbed.

EXPERIMENTS WITH ROOTS

To Prove that Roots Turn toward the Earth. If well-started seedlings be inserted in a split cork which is then put into a test-tube of water and inverted, it will be found that the upward pointing root will soon turn downward at the tip, as will all of its branches. This can be repeated with any kind of seeds. It would not do to infer a general rule from one or two cases.

If a germinating box with well-grown seedlings be turned on its side, the roots will turn down, no matter how often the

experiment be changed, thus proving the same thing in another way. Our experience with planting seeds in the garden also is a good experiment on the same line; the root turns down, no matter how the seed is placed.

The same experiments prove that stems turn *away* from gravitation's pull. This is called negative geotropism, and applies to most plant parts except roots. It is evident that what we call "weight" has nothing to do with the direction of either root or stem. The root, though not so heavy as the soil, penetrates it on its way downward, and the stem, despite its weight, turns upward, due to this effect of gravitation on all the living cells.

It might be thought that light had something to do with this change of direction in plant parts. How could it be decided by experiment?

To Prove that Roots Turn toward Moisture. If seeds be planted on the bottom of a coarse sieve which is then filled with wet moss and tilted at an angle of about 45 degrees, the direction taken by the roots will be different from what might have been expected from the above experiment. The roots will start downward at first, directed by gravitation, but when they have penetrated the sieve, they will turn toward it again and reënter the moss in order to find moisture.

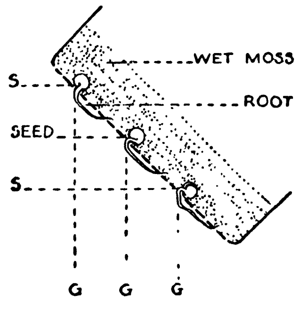


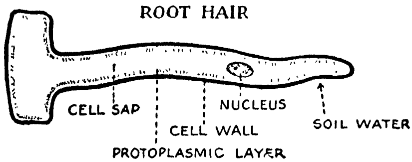
FIG. 16. An experiment to show hydrotropism. Seeds are planted in an inclined sieve filled with wet moss. If influenced by geotropism *alone*, the roots would grow downward toward G. They actually turn toward the moisture in the moss showing hydrotropism.

This response of roots to moisture (hydrotropism) will cause roots to turn toward a water supply if the surroundings be dry, even though they turn partly away from the direct downward line.

To Demonstrate Osmosis. Fill an artificial diffusion shell (such as can be purchased from dealers in laboratory supplies) with molasses and fasten it tightly to a long glass tube by

wiring it to a rubber stopper through which the tube is inserted. Insert the shell in a jar of water. Here are the three essentials for osmosis. The shell is the osmotic membrane; the molasses, the dense liquid; the water, the less dense liquid.

A suitable clamp is needed to support the shell and its tube so that the former does not touch the bottle, and to hold it at such a height that the liquid in the tube shall be level with



ESSENTIALS	EXPERIMENT	ROOT HAIR
DENSE LIQUID	SUGAR SOLUTION	CELL SAP
MEMBRANE	OSMOTIC CELL	PROTOPLASMIC LAYER INSIDE THE CELL WALL
LESS DENSE LIQUID	WATER	SOIL WATER

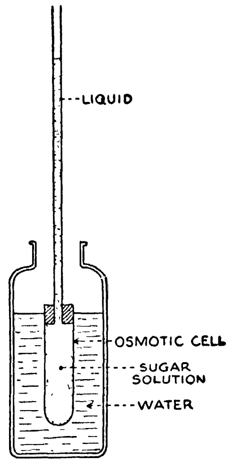


FIG. 17. Essentials for osmosis in root hair and in laboratory apparatus.

the surface of the water in the bottle. In place of the diffusion shell, other membranes can be used; a piece of bladder membrane fastened over the open end of a funnel tube will act as an osmotic membrane. The thin skin which lines a hen's egg will act in the same way if the shell be carefully removed at one end and a tube inserted at the other and sealed with wax. In neither of these will the rise be so rapid or certain as with the diffusion shell, which should be used if possible.

The rise in the tube usually reaches a height of several feet. This illustrates in a way the action of a root hair in causing root pressure, though the root hair, because of its protoplasmic lining, *selects* what will be absorbed, while the apparatus does not.

With the same apparatus, starch or protein or fat can be placed in the shell, and it will be found that no osmosis goes on, and that they cannot be found in the water outside the diffusion shell. On the other hand, the sugar, peptone, or other *soluble* food stuff, will pass through the membrane, and can be found by test in the water outside.

Not only does plant absorption depend upon osmosis but nearly all the life processes of plants and animals utilize this process in some degree, as will be seen as we proceed.

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Geotropism

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Hydrotropism

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Osmosis

(See references at end of Chapter LVI.)

SUMMARY OF CHAPTER IX

OSMOSIS

1. Necessity of water for plants.
- a. Food.
- b. Transportation.
  - (1) Food, mineral matter, etc.
  - (2) Oxygen.
  - (3) Waste.
- c. Turgescence.
  - (1) Meaning of term.
  - (2) Where it is active.
  - (3) Importance in absence of woody support.

2. Osmosis.
- a. Definition.
- b. Processes dependent upon osmosis.
  - (1) Absorption.
  - (2) Assimilation.
  - (3) Digestion.
  - (4) Respiration.
  - (5) Excretion.

c. Essentials for osmosis	In plant	In experiment
Membrane	Root hair or cell walls	Diffusion shell
Dense liquid	Cell sap	Sugar solution
Less dense liquid	Soil water	Water in bottle

3. Root hairs.
- a. Structure (see diagram).
- b. Adaptations for absorption.
  - (1) Large extent of surface.
  - (2) Thin walls for osmosis.
  - (3) Location for protection and large contact with soil.
  - (4) Acid secretion to dissolve mineral matter.

4. Geotropism (contrast action of mere weight).
- a. Definition.
- b. Functions.
  - (1) Penetration of soil.
  - (2) Obtaining water in soil.
  - (3) Obtaining nourishment.
- c. Kinds.
  - (1) Positive in roots.
  - (2) Negative in stems.

5. Hydrotropism.
   a. Definition.
   b. Function.

6. Selective absorption.
   a. Meaning of term.
   b. How controlled.

7. Successive osmosis.
   a. Meaning of term.
   b. Explanation.

8. Root pressure.
   a. Meaning of term.
   b. Reverse osmosis.

9. Experiments with roots.
   a. Geotropism.
   b. Hydrotropism.

CHAPTER X

STEMS: THEIR FORMS AND FUNCTIONS

Vocabulary

Node, the point on a stem at which a leaf is attached.
Propagate, to reproduce a plant or animal.
Terminal, end.
Lateral, side.
Excurrent, a type of branching producing a slender tree.
Deliquescent, a type of branching producing a spreading tree.

As we look at a tree in winter, standing gaunt and tall against the background of snow we can see in complete detail its whole stem system. Bare and dead enough in appearance, to be sure, yet we know that with the coming of spring, it will be clothed with leaves, that blossoms may perhaps adorn its bare twigs, and that fruit of some sort will probably hang from its branches.

Stems are not always large and strong like the tree trunk but may be delicate and slender like those of some roadside flower which lives but a year and is killed by winter's frosts. Whether large or small, the typical stem has the same general functions to perform, which are as follows:

Stem Functions.

1. To expose the leaves to light and air.
2. To support flowers for pollination.
3. To support fruit for dispersal.
4. To connect the two food-getting organs, roots and leaves.
5. To transport liquids upward and downward in the plant.
6. To serve as storage place for food stuffs.
7. To propagate the plant (in some cases).

These functions are numerous, widely different, and of vital importance to the plant. There are many ways of adaptation for each function, hence stems of different plants vary greatly in structure and appearance, from that of the wild

flower nodding in the breeze to the lofty trunk of a three hundred foot redwood tree.

Stems may grow under ground or under water; they may be slender climbers or thick fleshy storehouses of food; they may live but a season or endure for centuries; yet they perform some and usually several of the functions mentioned above.

The most apparent function of the stem is the support of leaves, flowers, and fruit. Leaves must be exposed to light, flowers must be reached by wind or insects if they are to be pollinated, and fruits must be so supported that they shall be scattered by some of the various methods mentioned in Chapter XV. In large plants like shrubs and trees especially, these ends are attained by various methods of branching. The branches of a stem originate as buds and the arrangement and development of the buds is the cause of the various kinds of branch systems.

Branching Due to Leaf Arrangement. Buds may be located at the ends of the stems, in which case they are called terminal (end) buds, or they may grow at the sides of the stems and are called lateral (side) buds. Lateral buds nearly always grow in the angle just above the leaves. Thus if the leaves are opposite each other on the stem, the branching will be opposite also. If the leaves are alternately arranged, the branches will arise in the same order.

Examples of the opposite arrangement are found in the ash, maple, and horse-chestnut. The alternate type is represented by the elm, oak, beech, and apple. In either case the chief object is the exposure of the leaves to light. This is accomplished in various ways depending upon the development of the branch buds and the twisting of the leaves themselves so as to face the light and, at the same time, shade each other as little as possible.

Branching Due to Bud Development. If the terminal bud keeps in advance of the lateral buds, a slender, cone-shaped outline results, called the *excurrent* type, such as is shown in the pines and spruces.

Such trees have several advantages:

1. They grow rapidly above their neighbors.
2. Their slender, flexible tops offer little resistance to storms.
3. They can grow close together and still let light down to the lower branches.
4. Their lower branches can bend and shed snow easily.

For these reasons the excurrent type is particularly adapted to cold northern regions, where it is most frequently found.

Deliquescent. If, on the other hand, the lateral buds equal or exceed the terminal ones, the plant assumes a broad spreading outline called the *deliquescent* type as shown by the elm, apple, and oak. This type is very successful in competition with other forms, because, even though it may start late, its broad top shades and kills its neighbors. All plants which grow mixed with these broad-shouldered and broad-leaved giants must either get a start before the leaves come in the spring or else must have learned to live with very little light.

Forked Branching. Indefinite Branching. The growth of the terminal bud may be checked by bearing flowers. If so, the branch usually forks in a Y shape, producing round-topped plants, such as the horse-chestnut and magnolia. In some shrubs the terminal bud is unprotected for winter, hence is killed back and thus produces a very irregular type of branching, called *indefinite*. This is well illustrated by the sumach.

Modification of Stems

As would be expected, stems are variously adapted to suit different conditions and functions, thus giving rise to many forms.

Shortened Stems. In some plants like the dandelion, the stem is so shortened that the leaves seem to come in a rosette, directly from the top of the root. On this account, the term "stemless" is sometimes applied to such cases. These low-growing plants have many advantages, among which may be mentioned:

Escape from grazing animals.

Escape from crushing by being stepped on.

Crowding away neighbors by the wide, close leaves.

Water is retained near the root, by the cover of leaves above.

Creeping Stems. The creeping stem is another type, with common examples, such as the strawberry, in which a plant, though having a weak and slender stem, is, with great economy of wood tissue, enabled to spread its leaves widely. By this habit it also escapes injury from wind, cold, or storms, since it is closely attached to the earth at frequent intervals. Besides, these "runners," as the horizontal branches are called, furnish a valuable means of propagation, since they send out roots at the nodes, and grow even if separated from the parent plant.

Climbing Stems. Many stems succeed in exposing their leaves to the light without producing much more supporting tissue than do the creepers. These are the climbing stems which use supports outside of their own structures to lift themselves into the light. One means of climbing is by twining round some supporting plant, as in case of hops and pole beans. Another similar method is by means of tendrils, which are usually leaves reduced to the mere skeleton of veins, as in the grape, wild cucumber, etc.

FIG. 18. Wild bean climbing by twining. Note the extended tip which will swing in a circle till a support is reached.

The coiling of tendrils or of twining stems is a curious process, for it frequently seems as though a plant or tendril had started straight for a certain support and deliberately coiled about it. This is not the case though the real process is scarcely less wonderful. The tip of the twiner or the tendril grows unequally on different sides, causing it to swing through the air in circles, as it grows. Thus it has a chance to reach anything within the radius of its swing, which is often several inches.

Having reached a support, the growing point can no longer swing as a whole, but the tip coils about the support as it grows, enabling it to rise as high as its sturdier neighbors. Tendrils

also coil between the support and the plant, raising the latter and holding it by a spring which will yield to wind pressure without breaking. This later coil usually reverses midway to avoid twisting the tendril off.

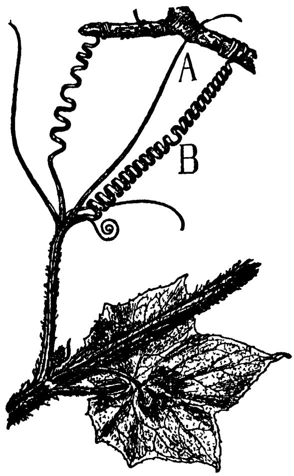


FIG. 19. Burr cucumber climbing by tendrils. A, tendril about to clasp a support. B, Tendril with reversed coils drawing the plant up to the support.

Other methods of climbing are found in plants like the poison ivy, which produces adventitious roots to attach itself, and in the nasturtium, which climbs by hooking its leaf stalks around the supports.

In any case, the climbing habit is very successful, especially in crowded tropical forests where the shade renders necessary some means for a slender plant to reach up into the light to display its leaves. This the climbers do with least possible outlay of wood tissue.

Fleshy Stems. Another modification of stems which frequently occurs is developed for the storage of food. The stem assumes a fleshy form, allowing a large storage volume with little exposure of surface. Such fleshy stems are usually developed underground in order to protect their stored food from animals and cold. Like the fleshy root, these underground stems enable the plants to get an early start in spring and also often propagate the plant very successfully. The simplest underground stem is the *root stock* found in sweet flag and Solomon's seal. Other common forms are the *tuber* of the potato, and the *bulbs* such as the onion, lily, and tulip. These seem more like roots than stems, but their manner of growth, their internal structure, and the fact that they bear leaves, all show that they are really stems, though greatly modified for food storage and propagation. Stems may grow in the ground and roots may grow in the air; it is their function and structure that decides whether they are the one or the other.

Bud Structure. A bud is really an undeveloped stem with the spaces between its leaves greatly shortened, and the leaves themselves very small and closely packed. The chief function of a bud is to keep the growing point of the stem protected from harm and yet ready for rapid growth at the right time. To carry out this purpose, buds have several interesting adaptations.

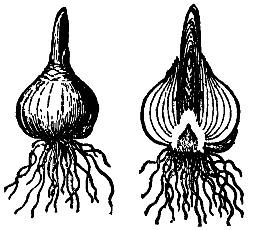


FIG. 20. A hyacinth bulb. A type of underground stem. In the section notice the shortened stem from which the roots are growing. The layers are fleshy leaves containing stored food for the shoot which can be seen within.

In the first place, they are usually covered with small leaf-like organs called bud-scales, which overlap as shingles do, and protect the tender shoot from loss of water, mechanical injury, rain, and insect attacks. Often the scales are covered with a sticky gum which aids it, especially as regards the control of water.

Within the bud, the tiny leaves are frequently packed in a woolly down which helps protect from injury, especially when the bud is first opening, and may also prevent ill effects from sudden changes of temperature. The leaves themselves are wonderfully packed, so as to expose little surface, and economize space; they may be folded, rolled, or coiled, but always in the same way in the same plant.

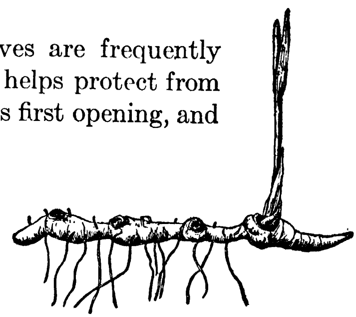


FIG. 21. Underground stem of Solomon's seal with branch just starting upward and roots extending downward. The three scars mark the location of the shoots of the three previous years.

Buds are usually developed either at the end of the stem (terminal), or just above the leaves (lateral). Their growth consists of three stages, the opening of the scales, the lengthening of the stem, and the expansion of the leaves. The scales fall off during this process, leaving the bud-scale scars to mark their former place. As most buds begin growth in the spring, these rings of scars

mark the beginning of each year's growth. The age of the stem can thus be calculated as long as the scars show.

COLLATERAL READING

Studies in Plant Life, Atkinson, pp. 33–39; *Lessons with Plants*, Bailey, pp. 1–44; *School and Field Botany*, Gray, pp. 27–32, 69–70; *Plant Relations*, Coulter, pp. 53–87; *Botany for Schools*, Atkinson, pp. 37–60; *Text-book of Botany*, Gray, pp. 45–51, 69–85; *Kerner and Oliver*, Vol. I, Part 2, pp. 465–482, 710–736; *Plant Life and Uses*, Coulter, pp. 143–198; *Experiments in Plants*, Osterhout, pp. 224–285; *Plants and their Children*, Dana, pp. 112–124; *Applied Biology*, Bigelow, pp. 163–188; *Structural Botany*, Gray, pp. 50–64, 70–82; *Plant Structures*, Coulter, pp. 280–296; *Lessons in Botany*, Atkinson, pp. 61–68; *Elementary Studies in Botany*, Coulter, pp. 224–252.

SUMMARY OF CHAPTER X

STEMS

1. Functions of stems.

- a. Support { of leaves for light and air. / of flowers for pollination. / of fruits for dispersal. }
- b. Transportation of liquids between root and leaf.
- c. Storage of food.
- d. Propagation.

2. Branching.

- a. Object of branch arrangement in general.
- b. Branching due to leaf arrangement.
  - (1) Opposite.
  - (2) Alternate.
- c. Branching due to bud development.
  - (1) Excurrent.
    - (a) Shape of tree.
      - (1) Cause.
    - (b) Advantages.
      - (1) Rapid growth in height.
      - (2) Little storm resistance.
      - (3) Can grow closely.
      - (4) Shed snow readily.
    - (c) Examples.
  - (2) Deliquescent.
    - (a) Shape of tree.
      - (1) Cause.
    - (b) Advantages.
      - (1) Shades out its neighbors.
      - (2) Few can grow together.

(c) Examples.
(3) Forked.
(4) Indefinite.

3. Modification of Stems.

a. Shortened stems.
(1) Advantages.
(a) Escape grazing animals, or crushing.
(b) Crowd away neighbors.
(c) Retain water at roots.
(2) Examples.
b. Creeping stems.
(1) Advantages.
(a) Wide spread, little wood.
(b) Escape injury.
(c) Propagation.
(2) Examples.
c. Climbing stems.
(1) Advantages.
(a) Escape from shade conditions.
(b) Expose leaves with little wood tissue.
(2) Means of climbing.
(a) Twining.
(1) Method of operation.
(2) Examples.
(b) Tendrils.
(1) Method of operation.
(2) Examples.
(c) Adventitious roots.
(1) Examples.
(d) Leaf stalks.
(1) Examples.
d. Fleshy stems.
(1) Advantages.
(a) Safe storage.
(b) Early start.
(c) Propagation.
(2) Examples.

4. Buds.

a. Definition.
b. Function.
c. Adaptations.
(1) Scales.
(2) Gum or hairs.
(3) Woolly packing.
(4) Leaf arrangement.
d. Location.
e. Manner of growth.
f. Bud-scale scars.

CHAPTER XI

STEM STRUCTURE

Vocabulary

Lenticels, openings in the bark for passage of air and water vapor.
Radiating, extending out from the center.
Perennial, living year after year.
Dicotyledonous, having two cotyledons. (Dicots.)
Monocotyledonous, having one cotyledon. (Monocots.)

The chief functions of stems, as mentioned in the previous chapter, are support, transportation, and storage. Though this is true of nearly all stems, they achieve their purposes in many ways and with different types of structure.

There are usually woody tissues for support, tubular ducts for transfer of liquids, pith cells for storage, and some kind of an outer covering for protection. A region of growing cells which produces the other tissues is present at some stage of growth, but may be used up in certain parts as the stem gets older.

Arrangement. These tissues are arranged in a different way in each of the large groups of plants. Those whose seeds have two cotyledons, have stem tissues arranged in more or less regular rings, such as are found in most common trees. Plants with one cotyledon have the wood and ducts grouped in little bundles which are scattered irregularly through the stem as shown in the corn stalk. Pines and their relatives have stem tissues in rings but differ from dicotyledons in many ways. Ferns and their relations have a still different arrangement.

It is hard to say why stem structure seems to correspond with seed structure, but it is a fact that these groups of plants usually have seed, stem, and leaf characteristics similar within each group.

We shall study only the dicot and monocot types of stems, taking as an example of the former, the horse-chestnut, and of the latter, the corn. In each group there are both larger and

smaller members than these examples; dicots include delicate plants like the violet and great trees like the oak. Monocots cover forms as different as the slender grass and the lofty palm, but in general the stem structure of the plants selected is fairly typical.

External Structure of a Dicotyledonous Stem

The external structure of all ordinary dicot stems, though varying greatly, has some points in common. It will be seen that there is an outer covering, the bark, which protects from injury by storm and insects and prevents undue loss of water, as a result of drought or cold.

Lenticels. Through this bark are openings (lenticels) which permit a regulated escape of water-vapor, and also admit air.

Leaf Scars. On the bark will be found scars left by leaves of preceding seasons, varying in location according as the leaves were opposite or alternate, and having above them the buds for the coming year's branches. On these scars will be found dots marking the severed ends of the ducts which can be traced into the stem and found to extend to the roots. Over these scars is a water-proof coat (abscission layer) which formed *before* the leaf fell to protect the plant against the loss of so many leaves and consequent bleeding from thousands of tiny wounds.

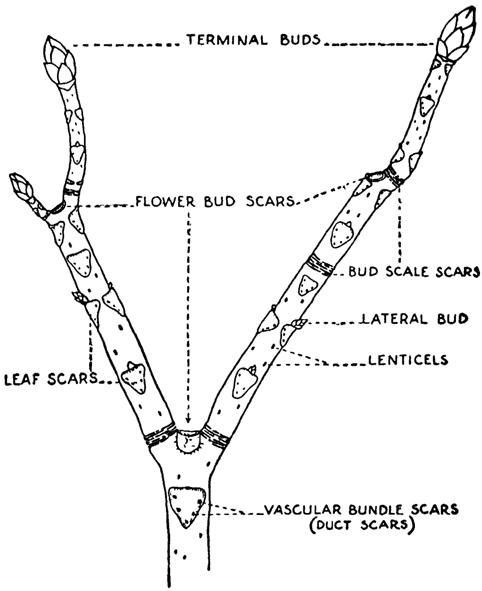


FIG. 22. External structure of stem of Horse-chestnut.

Flower-bud and Fruit Scars. It frequently happens that the bearing of a flower or fruit makes a scar differing from those made by falling leaves. These are especially plain in the horse-chestnut. A flower-bud always ends the growth of the stem that bore it, hence further growth is by lateral buds which produce a forked type of branching, where the flower was borne.

Bud-scale Scars. At various places on the stem are rings of small scars caused by the bud-scales of previous years which were shed as spring activity commenced, thus marking the first growth of each year. Other markings are frequently met with, caused by injuries from weather or insects. These the plant has met by thickening its bark.

Internal Structure

On cutting across the stem of any common tree, the general internal structure will be shown, in most cases, without the use of lenses. Three regions can be distinguished easily—bark, wood, and pith. A closer inspection reveals a fourth, between bark and wood. This is the cambium, a thin, light-colored zone of very juicy cells, which here, as in the root, produces all the other tissues.

Wood. The wood will be seen to be arranged in circles, "annual rings" of alternately coarse and fine tissue, the ducts, and wood fibers, while radiating from the pith and extending across these rings are the pith rays that connect pith and bark.

Bark. The bark will repay a closer scrutiny with a hand lens and will be found to consist of an outer epidermal layer, often variously thickened and roughened by growth; next, the "green layer" (cortex), and within this the bast fibers and tubes, which transfer liquids downward and give toughness to the bark.

Functions of Stem Tissues

The tissues included in the bark, mentioned in order from without, are epidermis, cortex, bast fibers, and bast tubes. Then comes the cambium, then the wood region which includes

wood fibers, ducts, and pith rays. In the center is the pith, whose rays extend through the wood to the cortex. Each of these layers has definite functions, several of which have been mentioned.

Epidermis. The outer layer, or epidermis, is protective in several ways. Its thickness guards against injury from wind, weather, and attacks of insects. It does not allow loss of water, except at the lenticels, thus preventing undue drying of the delicate tissues beneath. It also keeps out the spores of parasitic fungi that might otherwise find entrance and destroy the plant.

Cortex. Under the epidermis is the cortex, whose function is to help prepare food for the plant, much as do the leaves.

Bast Fibers. The bast fibers give toughness to the bark, sometimes helping support the stem. Man has taken advantage of the fiber strength of hemp and flax (look up) to make fabrics.

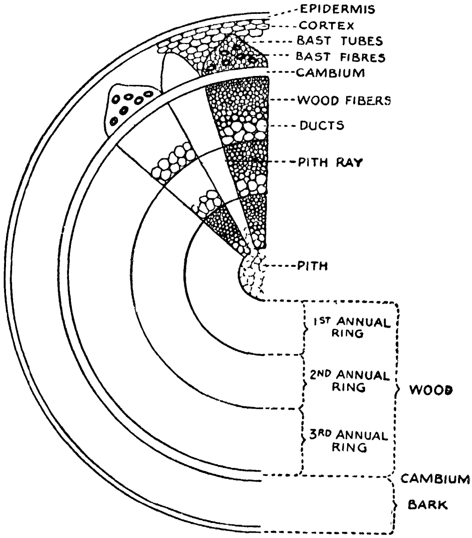


FIG. 23. Cross section of dicot stem (Basswood), showing arrangement of tissues. Greatly magnified.

Bast Tubes. The soft bast conveys food prepared by leaves downward to various places where it is used or stored.

Cambium. The growth function of the cambium cannot be too often mentioned, as from it, by a complicated process of cell division, bark tissues on the outside and wood and ducts within are formed.

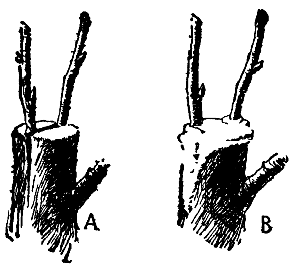
Ducts. The ducts transfer liquids up and air down in the stem, and add their strength to the woody portions, whose

fibers are the chief support of the stems of all larger plants. Together they make up the bulk of the stem tissue.

Wood Fibers. Both the wood fibers and ducts are arranged in very definite circles, called *annual rings* because usually each ring marks a year's growth. These rings are caused by the cambium which produces larger ducts and more of them in the spring when the sap is flowing than later, when more wood fiber is produced. In the winter, the growth practically stops, only to begin the following spring with a layer of large ducts again, thus marking, by these successive rings of tissue, the seasons' changes.

Pith. The pith may be a minute remnant of the formative tissue, or a larger storage place for foods and the pith rays serve as cross channels for liquids to follow in their circulation in the stem.

So we have one protective region, the epidermis; one digestive region, the cortex; one formative region, the cambium; one storage region, the pith. The ducts, soft bast, and pith rays are the channels for circulation of fluids while the wood and bast fibers are for strength and support.



From Bailey.

FIG. 24. A common method of grafting. A, insertion of new branches in split stem at the cambium region. B, the wound protected with wax to prevent drying of tissues.

Grafting. The remarkable ability of the cambium cells to grow and produce new tissues is utilized in grafting. Grafting consists in bringing into close contact the cambium layer of a small active twig with that of the tree upon which it is to grow. This may be done by splitting the stem, and inserting the fresh-cut twig, or by raising the bark and inserting an active budded twig beneath it, with the cambium layers in contact. The wound is then protected by wax and growth between the two cambium layers soon unites the new stem with the old.

The cambium also provides for the healing of injuries and the

covering of scars where branches are cut off. New tissue forms at the edges of the wound and gradually covers the whole area, provided that spores and bacteria do not first cause decay of the exposed surface. To prevent this, cut or injured surfaces should always be tarred or painted to kill and keep out bacteria, while new tissue is growing. If decay has begun the rotted wood must be cleanly removed, the cavity sterilized

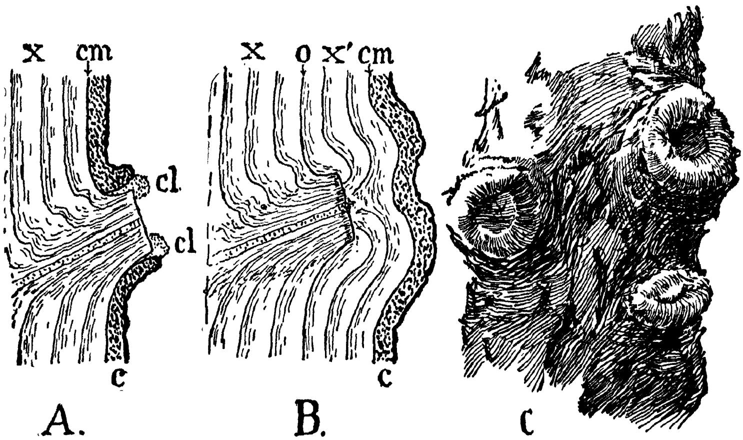


FIG. 25. Steps in the healing of a wound caused by removal of a branch. A, the fresh wound with new tissue (cl) just forming. B. the same wound three years later showing layers of wood (x') over the cut. C, external view of similar wounds in process of healing. x, wood layers; cm, the cambium; o, position of cambium when branch was cut; c, the bark.

with tar and filled with cement. The cambium growth will now extend the tissue inward from the edges and often cover the scar, filling and all.

In rare instances two limbs, or even two separate trees of the same kind, will chafe together in the wind, till the cambium is exposed in both. Then if undisturbed, an automatic graft may occur and a curious condition will develop, in which the two trees will continue to grow firmly together.

Girdling. If the bark and cambium be cut away, in a ring completely around a tree it is called girdling the tree. This may be done by gnawing animals, such as rabbits or mice, which eat the tender under bark in winter, or it may be done

purposely, when one wants to get rid of a tree. In either case, the result is the same, the tree will die because food can no longer get down from the leaves to the roots. If girdled in winter, it may leaf out in the spring, since the uncut wood ducts can carry food up from the roots, but none can get down, and the following year finds the tree dry and dead.

When valuable fruit trees are thus damaged, parts of small twigs are sometimes grafted across the girdled region, and in this way the life of the tree is saved. Some trees of the willow family will send out roots from just above the girdle, and if they can reach moist ground the tree will survive.

Pruning. Trees, shrubs, and vines often have surplus branches cut off. This is called pruning and is done for various reasons. In fruit trees it may be to keep the tree in such shape that the fruit may more easily be picked, or to prevent the growth of unnecessary leaves and branches, so that more nourishment will go to make fruit.

Shade and ornamental trees are pruned to keep them in the desired shape and size. When trees are transplanted, many of the branches are pruned, so that there will not be so much foliage to demand water from the roots until they have had time to get a start in their new place. If the full leafage were left on, the roots could not supply sufficient water and the tree would die.

Vines have to be pruned so that they will keep within the bounds of their supports and also to make them bear more fruit and fewer leaves. Hedges are sharply pruned to keep them in the desired shape and prevent spreading.

As a rule, pruning should be done in winter or when the sap is not rising, so that the cut ends will not "bleed" and thus lose the food-bearing sap and weaken or kill the tree.

Structure of a Monocotyledonous Stem

Corn Stems. The common corn stalk is a good example of the monocotyledonous type of stem. If we cut a section across it, we find the tissues very differently arranged from those in

the dicotyledonous stem, just discussed. The monocotyledon, in place of a bark of several layers, has a *rind* of only one kind of tissue—thick-walled, hard cells whose function is mainly to support the plant. The wood, cambium, and bast tissues are grouped in numerous *vascular bundles*, which, instead of being in definite rings are scattered through the stem, the larger and older ones toward the center and smaller and younger ones near the edge. The *cambium* in monocotyledons ceases to build new tissue, after a time. Hence the stem does not continue to increase in diameter as does the dicotyledonous stem, but produces tall slender plants like corn, grasses, bamboos, and palm trees. The bulk of the stem consists of the soft thin-walled *pith*, instead of wood and ducts, so that the structure is almost reversed in these two types of stems although the same tissues are present. As one result of this striking difference we obtain many of our wood products from the dicotyledonous stems, while the monocotyledonous, having little wood and much pith for storage, provide us with foods such as hay and grain, sugar-cane, and starch.

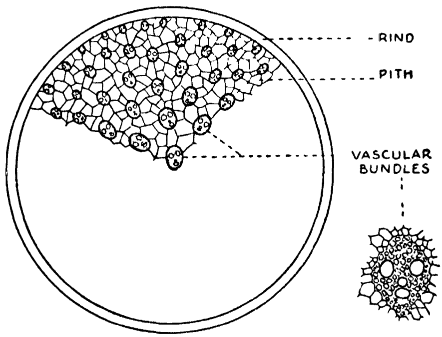


FIG. 26. Cross section of monocot stem (corn), showing arrangement of tissues and one vascular bundle enlarged.

Do not think that the monocotyledonous stem is weak because it has so little wood tissue—the case is quite the contrary as you may prove for yourself. Select a tall grass stem, such as timothy or rye. Measure its height and its diameter. How many times its thickness is the height? Suppose it were a tree one foot in diameter how tall would it be? Compare this with the actual height of trees. Figure this out and you will have more respect for the strength of the grass stem, as well as for the "sturdy oak."

Courtesy U. S. Dept. of Agriculture.

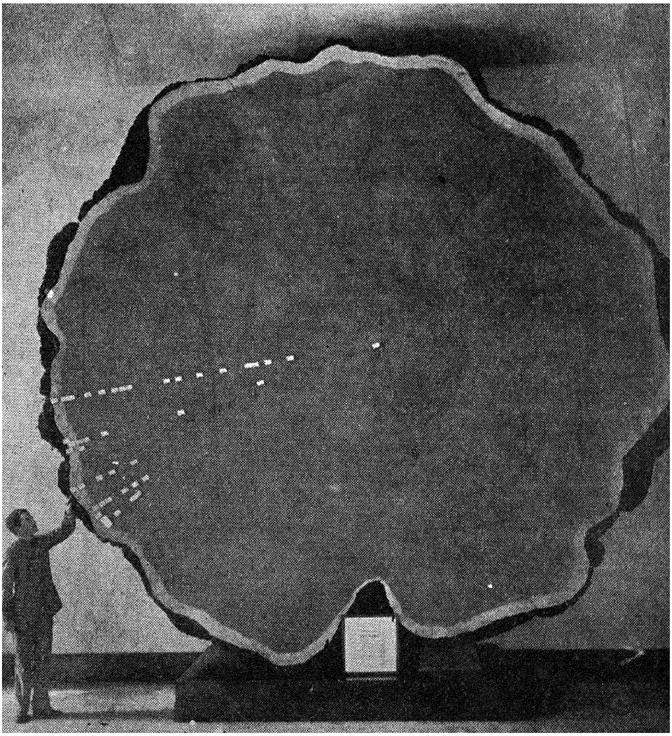
FIG. 27. A sequoia or "big tree" of California, about 250 feet in height, 30 feet in diameter and perhaps 1,500 years old. These trees are probably the largest and oldest of living things.

Polycotyledonous Stems. Seeds having several cotyledons (polycotyledonous) have a woody stem with annual rings but differ in other ways from the two preceding types. We shall not take up its structure in detail; pines, spruces, and all evergreen trees belong to this last group and their resinous wood furnishes us with some of our best lumber.

Not only are their stems of great strength, but some of them are the largest and oldest living things in the world. The Big Trees (Sequoia) of California are the oldest, even among trees. One of these ancient giants, the "General Sherman Tree," is nearly four thousand years old, 279 feet high, and 36 feet in diameter.

To put it another way, it was a flourish-

ing sapling, twenty or thirty feet high, when the Exodus of Israel and the Trojan wars took place. It was a thousand years old at the time of Solomon and two thousand at the



Courtesy of the American Museum of Natural History.

Fig. 28. Section of one of the big trees of California, the "Mark Twain," 16 ft. in diameter, and 1,341 years old. The cards mark the diameter of the tree when various historical events occurred, dating well back into the sixth century. This is relatively a small and young tree!

birth of Christ. All our European and American history are but events of yesterday to this patriarch of the organic world, which now towers higher than a twenty-story building and is still growing. Some animals, such as the elephant, may live

two hundred years, but even these, or man, with his three score years and ten, are the merest infants beside such ancient inhabitants of the vegetable world.

This illustrates a fact which is often overlooked, that perennial plants really have no limit of growth, as do animals, but keep on increasing slowly in size for indefinite periods, while animals reach a maximum size and grow no larger, no matter how old they become. The reason is probably that in plants, little energy is required, hence little food is used in oxidation and more is left for additional growth, whereas in animals, which use more energy, a point is reached, where the nutritive processes are just balanced by oxidation and further growth ceases. As soon as the destructive processes exceed the constructive, old age enters and finally death itself.

COLLATERAL READING

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SUMMARY OF CHAPTER XI

STEM STRUCTURE

1. Dicot Stem Structure.

External Features	Structure	Function
Bark		Protection
Lenticels	Spongy openings	Let out water vapor Admit air
Scars left by		
1. Leaves showing		
Duct scars	Cut ends of ducts	
Abscission layer	Water proof cover	Prevent loss of sap
2. Bud scales	Formed in spring	Mark year's growth
3. Flowers and fruit	Usually terminal	Cause branch to fork

Internal Features	Structure	Function
1. Bark		
Epidermis	Thin if young, corky in older stems	Protect from insects, fungi and weather Retain water
Cortex	Thin walled, soft cells	Food making and digestion
Bast fibers	Thick and tough	Strength
Bast tubes	Long, tubular cells	Downward transfer
2. Cambium	Very active, protoplasm	Growth
3. Wood region		
Wood fibers	Thick walled, stiff	Support
Ducts	Thick walled, tubular	Upward transfer
4. Pith	Thin walled, weak	Storage
Pith rays		Cross transfer

2. Comparison of Dicot and Monocot Stems.

Features of each	Dicot	Monocot
Outer layer	Bark of several tissues	Rind of one tissue
Vascular bundles	In regular rings	Scattered
Bulk of stem	Wood	Pith
Supported by	Wood region	Rind
Cambium	Permanent	Not permanent
Growth	Continuous in height and thickness	In height only
Use	For lumber, fuel, etc.	For food stored
Usual shape	Thick	Tall, slender
Examples	Broad-leaved trees and common plants	Grasses, lilies, palms, sugar-cane, etc.

3. Polycot stems.

4. Grafting.

5. Girdling.

6. Pruning.

CHAPTER XII

LEAVES AND LEAF STRUCTURE

Vocabulary

Petiole, leaf stem.
Stomates, openings in leaf epidermis to admit air and let out water vapor.
Heliotropism, the response of plant parts to light.
Chlorophyll, the green coloring matter of plants.
Transpiration, the passing off of excess water from plants.
Vascular, composed of "vessels" or tubular cells, such as the vascular bundles of ducts in stem and leaf.

Leaf Functions. The *leaf* is one of the most remarkable and important parts of the plant. Within it are performed more life functions than in any other plant or animal organ. Its chief and unique function is the manufacture of sugar and starch out of water from the soil and carbon dioxide from the air. Animals cannot prepare carbohydrates from these two compounds and must therefore depend upon plants for their supply. Not only does the leaf prepare, but it also digests and assimilates food, sending its surplus, by way of the veins (duct bundles), to all living parts of the plant. Furthermore, the leaves are constructed so as to admit air for oxidation, and to throw off carbon dioxide (respiration). Excretion of water (transpiration) and of other wastes is another function of these versatile organs. They also possess in some degree the powers of motion and reproduction. Food making, digestion, assimilation, respiration, excretion, motion, reproduction, —these are all the functions that any living thing can perform. One chiefly, and all to some extent, are performed in the leaf.

General Structure of Leaves

A leaf usually consists of a thin flattened portion (the *blade*) stiffened by a framework of veins which are really bundles of ducts connecting with those in the stem. Usually the blade

is attached to the stem and held out into the light by a stalk (the *petiole*). Its point of attachment is called the *node* of the stem, above which all branch buds originate. The *veins* may form a network throughout the leaf or may be almost parallel (grass). There may be one large midvein with branches like a feather (elm), or several veins of equal size may spread from the petiole like the fingers of your hand (maple), but whatever the arrangement, their function is to support the blade and transfer the liquids concerned in the various leaf processes.

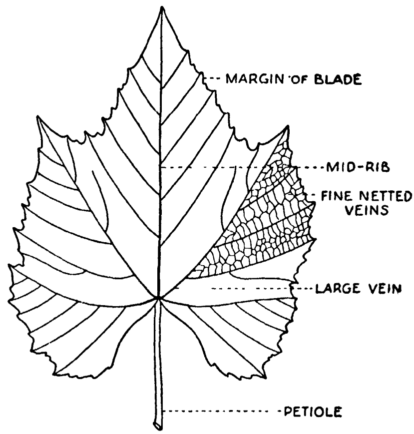


FIG. 29. General structure of leaf.

Leaf Forms. The outline of a leaf depends largely upon the arrangement of its veins. If netted veined, the leaves are usually broad, notched, or lobed. If the veins are parallel they are usually long and slender. The forms of the leaves are almost as various as the kinds of plants; some having regular or entire edges (lily), others notched, lobed, or finely divided (elm, maple, carrot), while still others are composed of separate leaflets (pea, horse chestnut), and so are called compound.

ADAPTATIONS FOR EXPOSURE

Form. These different-shaped leaves are developed with one end in view—the complete exposure of the leaf tissues to light and air, on both of which the activities of the leaf depend.

Arrangement. Not only are leaves adapted by their shape for this exposure but also by their arrangement on the stem. Look at a tree from above or at a house plant from the "window side" and observe that the branches and leaf stems (petioles) have so extended and twisted themselves, that each leaf is exposed and very few cast any shade upon their neighbors.

Heliotropism. Another adaptation for leaf exposure is their ability to constantly turn themselves toward the light. This is an every day observation, but no one can explain just *how* they do it. The process is called *heliotropism* (which means sun turning), and is very essential to the work of the leaves. Roots turn *from* light (*negative* heliotropism) while this response made by leaves *toward* the light is termed *positive* heliotropism.

From Atkinson.

FIG. 30. Heliotropism at work. A sunflower plant turning toward the morning sun.

Modified Leaves. Like roots, leaves are often modified to perform special functions. They may be reduced to mere tendrils for climbing (pea) or they may develop as thorns for protection (barberry). They may thicken up with stored nourishment and even reproduce the plant (live-for-ever), or most curious of all, may develop into traps for insects (sundew and pitcher-plant).

Fall of Leaves. Most plants of temperate climates shed their leaves either all at once in autumn (maples, elms) or a few at a time the year round (pines and spruces). In this way waste mineral matter that has accumulated is removed from the plant. In the case of the broad-leaved plants, this shedding also comes because it is necessary to reduce the exposed surface so that too much water may not be evaporated in the winter, when the roots can supply but little. Of course one can see another reason for plants that grow in climates where snow prevails during the winter. The weight of snow accumulated by the leaves would tend to break the plant down. In the case of the pines with their slender needles the snow is shed, and this reason does not apply.

The color changes of autumn are not due to frost entirely, but may be caused by anything which stops the activity of the plant. The beautiful yellows and reds that make our autumn a blaze of glory mark the withdrawal of certain valuable materials from the leaves, and the decomposition of the chlorophyll.

Before the leaves of a plant fall there is formed at each leaf base a waterproof layer (abscission layer) which prevents the loss of sap after the leaf is gone.

The enormous amount of ashes left when the leaves are burned gives some idea of the amount of unused mineral matter which the plant had stored there, and incidentally reminds us that plant ashes, whether from stems or leaves, are useful food materials for plants and ought to be put back on the soil for use another year.

From Atkinson.

Fig. 31. Heliotropism at work. The same sunflower plant at sundown with leaves turned toward the west.

Minute Structure of Leaves

The chief function of the leaf is the manufacture of food materials. To understand this, a thorough study of the minute structure is necessary.

If the blade of a leaf be cut across and studied with a microscope, the following tissues may be observed. Mentioned in order from the upper surface they are:

1. The cuticle (sometimes lacking).
2. The upper epidermis.
3. The palisade cells.
4. The spongy layer (traversed by veins).
5. The air spaces.
6. The lower epidermis (penetrated by stomates).

The Upper Epidermis. This usually consists of a single layer of cells often very irregular, as seen from above, but brick shaped when viewed in cross section. There are few stomates in the upper epidermis, since they would be exposed to dust and rain. The function of the upper epidermis is to prevent loss of water. To aid in this, it is sometimes covered by a waxy layer called the *cuticle*, as in ivy, cabbage, and other leaves that shed water in drops. A second function of these epidermal cells may to be to act as lenses and concentrate the sunlight upon the inner parts of the leaf. The fact that their upper and lower surfaces are curved like a lens leads to this supposition.

The Palisade Layer. Next beneath the upper epidermis is the palisade layer. It consists of long narrow cells, placed

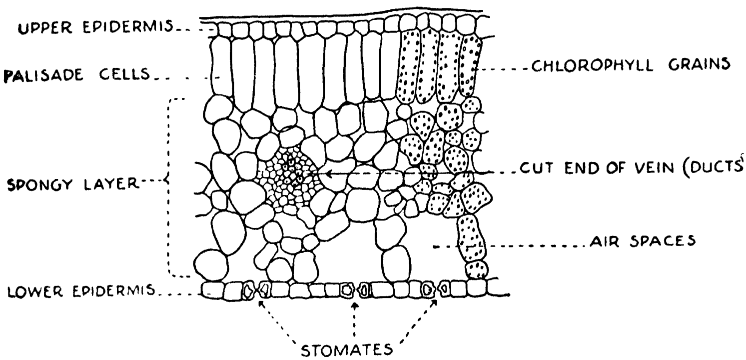
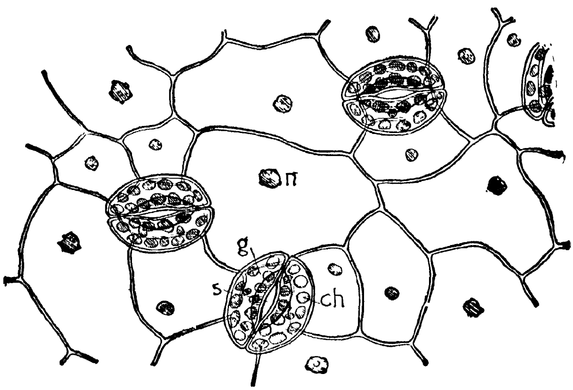


FIG. 32. The minute structure of a leaf shown in cross section.

endwise, at right angles to the surface of the leaf. Within these cells is found the *chlorophyll* which is the green coloring matter of all plants. As we learn later, it is very sensitive to light and these long cells permit the chlorophyll grains to move to the upper ends if the light is dim, or to retreat to the long side walls if the light is too strong.

The function of the palisade layer, then, is to regulate the exposure of chlorophyll to light, and to carry on the making of sugar and starch.

The Spongy Layer. Beneath the palisade layer is a spongy layer, which consists of thin-walled cells and air spaces and is penetrated in all directions by veins (duct bundles). The spongy cells are roundish, irregular, and loosely packed, thin walled, and full of protoplasm and chlorophyll. In them, as in the palisade layer, starch making and other leaf functions are carried on. The passing off of water to the air spaces is part of their work. The air spaces are usually large, irregular cavities among the spongy cells. They open through the lower epidermis by way of the stomates, their function being to receive water vapor from the spongy cells and to pass it out through these openings. They also permit oxygen and carbon dioxide to pass to all the cells of the spongy layer. They are very important, since through them food making, respiration



Courtesy of H. O. Hanson.

FIG. 33. Lower epidermis of leaf, showing stomates; s, opening of stomate; g, guard cells; ch, chlorophyll grains; n, nucleus or epidermal cell.

and transpiration go on. They occupy about three-fourths of the bulk of the spongy layer. The veins or duct bundles are scattered through the spongy layer transporting water and food stuffs and supporting the blade of the leaf.

The Lower Epidermis. Like the upper, the lower epidermis usually has but one layer of cells. Through it open many stomates which regulate the passage of air and water vapor to and from the inside of the leaf.

The Stomates. These have been referred to as openings through the epidermis. They are minute slit-like holes, about one-twentieth as wide as the thickness of this paper. On each side of the slit is an oval guard cell which regulates the opening and closing of the stomate. Controlled by the needs of the plant, the stomates open when there is an excess of water to be passed off, and close in a drought. They open when carbon dioxide is required for starch making or air for breathing, and close when either process stops, thus regulating, in a remarkable degree, the activities of the leaf. The function of the stomates is threefold:

1. To admit carbon dioxide for making sugar and starch.
2. To regulate transpiration of water vapor.
3. To admit oxygen and liberate carbon dioxide in respiration.

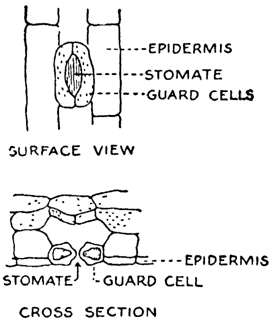


FIG. 34. Structure of stomate. (Greatly enlarged.)

However, this elaborate mechanism would be of little use were it not for the extensive system of air spaces in the spongy tissue of the leaf into which the stomates open, and by means of which all parts may have access to air for starch making, respiration, and transpiration. The number of stomates may vary from 60,000 to 450,000 per square inch and is usually greatest on the lower surface where they are best protected from dust and rain. Floating leaves have all their stomates on the upper surface. In vertical leaves they are evenly distributed.

Chlorophyll. The green coloring matter of plants is the most important part of the leaf. Practically the whole function of the rest of the leaf is to expose the chlorophyll to light and provide it with materials upon which to work. Chlorophyll is a complex substance composed of carbon, hydrogen, oxygen, nitrogen, and magnesium. Its action is aided by small amounts of iron compounds. It is found in the form of very minute particles called chlorophyll grains, which seem to consist of active

protoplasm combined with the green chlorophyll. This is the substance which performs the essential function of the leaves. It is found mainly in the palisade cells and spongy layer. The former are arranged to regulate its exposure to light, and the latter to provide it with carbon dioxide and water to use in sugar and starch making. We shall devote the next chapter to the way in which it does its work. For the present, think of chlorophyll as occurring in the form of active, green grains, found in all green parts of plants and very essential to their growth.

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Stomates

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Leaf Arrangement

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SUMMARY OF CHAPTER XII

LEAVES

1. Functions.

a. Making sugar and starch.
b. Digestion and assimilation.
c. Excretion.
d. Reproduction.

2. General structure.

a. Blade.
b. Petiole (leaf stalk) attached at nodes.
c. Veins (duct bundles).
    (1) Functions.
        (a) Support.
        (b) Transportation.
    (2) Arrangement.
        (a) Parallel (grasses).
        (b) Netted.
            Feather veined (elm).
            Finger veined (maple).
d. Outline.
    (1) Irregular margin in netted veined leaves.
    (2) Regular margin in parallel veined leaves.

3. Adaptation for exposure to light and air.

a. Shape.
    (1) To let light through to others.
b. Arrangement.
    (1) Opposite.
    (2) Alternate.
c. Heliotropism.
    (1) Positive (in leaves and flowers).
    (2) Negative (in roots).

4. Modified leaves.

a. Tendrils, for climbing (pea).
b. Thorns, for protection (barberry).
c. Thickened, for storage (live-for-ever).
d. Traps, for catching insects (sun-dew).

5. Fall of leaves.

a. Reasons.
    (1) Remove waste mineral salts.
    (2) Lessen exposure to storms.
    (3) Reduce surface for transpiration.
b. Cause of coloration.
c. Abscission layer.

6. Minute structure of leaves.

Parts	Structure	Function
Epidermis upper and lower)	One layer; irregular cells	Prevents loss of water
Stomates	Slit opening and guard cells; open into air spaces	Regulation of excretion Admit oxygen and CO_2
Palisade cells	Oblong, endwise to surface Have chlorophyll grains	Expose chlorophyll to light
Chlorophyll	Green, living grains in the protoplasm	Make sugar and starch
Spongy cells	Irregular, loose Have chlorophyll grains	All leaf functions
Air spaces	Large and irregular Connect with stomates	Excretion Respiration
"Veins"	Duct bundles extending from the stem	Support Transportation

CHAPTER XIII

LEAF FUNCTIONS

Vocabulary

Illumination, source and supply of light.
Liberated, set free.
Photosynthesis, the process of carbohydrate formation in leaves, uniting carbon dioxide and water by means of light.
Soluble, that which can be dissolved.

Photosynthesis. The process by which carbon dioxide from the air and water from the soil are combined by the leaves of plants to form sugar and then starch through the action of sunlight on the green coloring matter in the leaves is called photosynthesis (meaning combination by light). The chemical changes involved in this process are complicated, but some kind of sugar is produced which may be used by the plant at once, or may be changed to starch and stored as such.

This stored starch is what is commonly tested for in experiments with leaves as evidence of photosynthesis, and thus the process has come to be thought of as "starch making" whereas it would be more exact to call it "carbohydrate making" since both sugars and starches are involved. Photosynthesis is of fundamental importance since it is the starting point of food manufacture for plants and indirectly of animals also.

The ability of plants to take these two non-living substances and build up their own food from them makes the chief distinction between plants and animals, for the latter depend on plant foods either directly or indirectly. They cannot use the raw materials as do the plants.

Chlorophyll. The essential feature of the leaf, so far as photosynthesis is concerned is the green coloring matter, chlorophyll (leaf green). This, as described in Chapter XII, is found in the palisade cells and spongy layer, in the form of minute grains, embedded in the protoplasm.

Chlorophyll has the wonderful property of absorbing some of the energy of the sun's light and by the utilization of this energy it is able to combine carbon dioxide and water into sugar and starch. These are primary forms of plant food. At the same time oxygen is thrown off as a waste product. This replaces in the atmosphere, that which is used in respiration by animals. Therefore animals depend on photosynthesis for both food and oxygen supply. It is evident now why so many adaptations are found for exposing leaves to light, since, without light, carbohydrate-making cannot go on, and without such foods the plant cannot survive. The chlorophyll is placed in the long palisade cells so that, if the light is weak, the chlorophyll bodies may move to the upper ends of the cells and get better illumination; or if the light is too bright, they line up along the sides and so escape the direct rays. In the deeper tissue of the spongy layers of the leaf, the chlorophyll is sufficiently protected and does not need to move in this way; here we find the cells irregular in shape.

Materials Used in Photosynthesis. The water for this process is supplied from the soil through absorption by the roots. It rises to the leaves by way of the ducts and veins. Any excess is disposed of through the stomates. The carbon dioxide is supplied from the air, where oxidation, respiration, combustion, fermentation, and decay are constantly producing it. As fast as the plants remove it they return oxygen. As a result the composition of the air remains practically constant.

The Energy for Photosynthesis. The chemical energy of the sun's light, which causes the water and carbon dioxide to unite, is something that we know very little about, but is, nevertheless, a very real and a very great force. We realize that the sun gives us light to see by, and heat is evident enough, but when we think of how it tans our skin, bleaches our clothes, and makes our photographs, we have some evidences of the chemical action of light, though none of these can compare with the work done by these same rays in the leaf laboratory, during the making of sugar and starch in the plant.

This word photosynthesis can now be better understood,

meaning as it does "union by means of light," since it is by the chemical power of the light rays that the water and carbon dioxide are combined.

The leaf is sometimes compared to a mill in which the power is the sunlight; the machinery is the chlorophyll; the raw materials are the carbon dioxide and water; the products are sugar and starch; and the waste material is oxygen.

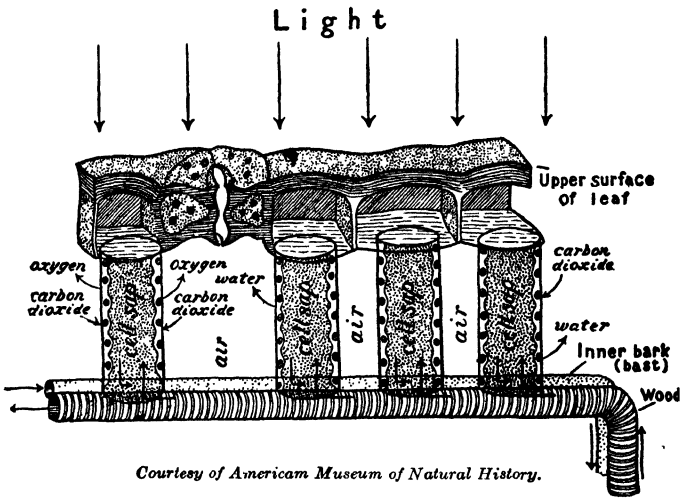


FIG. 35. Diagram showing some of the processes that go on in a leaf. Through the wood duct comes water and mineral matter from the soil. Through the stomate air is admitted, supplying carbon dioxide. Light acting through the chlorophyll grains in the cells, unites the water and carbon dioxide in the process of photosynthesis, forming carbohydrates and liberating oxygen. The carbohydrates are removed by way of the bast and the oxygen passes out from the air spaces through the stomates. The surplus water also passes off as vapor through the stomates (transpiration). Remember that this picture is diagrammatic and also that other processes go on in leaves.

The Waste Product. A benefit arising from photosynthesis almost as important as the production of starch itself, is the liberation of oxygen as a by-product. We have learned that every living tissue breathes *in* oxygen. The resulting oxidation produces the energy without which we could not live.

We have also learned that this oxidation produces carbon dioxide which we throw off in respiration. Now we can see that

the plants use this discarded carbon dioxide for making *their* food, and return to *us* the oxygen which is necessary for our life. This is a glimpse of one of the "circles of nature."

Other Leaf Functions. Carbohydrate making, while the most important, is not the only function of leaves. In their marvel-

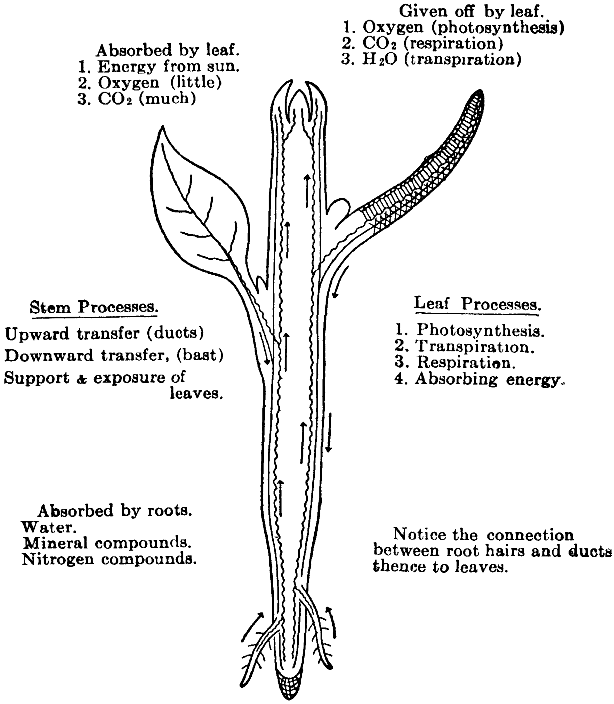


FIG. 36. Diagram showing plant processes in various regions and the routes followed by liquids in the root, stem amd leaves.

ous chemical laboratory go on the process of digestion, protein manufacture, assimilation, respiration, and excretion of water (transpiration). *Digestion* is necessary to put the food stuff into soluble form so that it may act in osmosis and flow through the ducts. As to *protein manufacture*, little is known, except that the carbon, hydrogen, and oxygen of the starch are combined with nitrogen, sulphur, and phosphorus from the soil water in

a way that we cannot fully understand, and that proteins are the result of the process.

Some plants also manufacture oils, gums, and resins from these same materials. The actual formation may go on in other parts, and the products may be stored or used in different regions, but the leaf produces much of the raw material and some of the finished products.

Assimilation is active in leaves and all other living parts of the plant, since this is the process by which the nutrients actually become part of the living protoplasm and tissue of the organism. *Respiration* (oxidation) goes on in all living plant tissues; while less active than in animals the process is just as essential, since it supplies the energy which keeps the plant alive. Much extra water is absorbed at times by the roots, in their transfer of nitrogen compounds and mineral salts from the soil. The useful elements are used in food making and the surplus water is passed off by way of the spongy layer, air spaces, and stomates. This process is called *transpiration* and differs from mere evaporation, in that the loss of water is regulated by the *stomates* and so corresponds to the needs of the plant. It does not depend upon the temperature alone, as does evaporation.

We find in the leaf the processes of food manufacture, digestion, and assimilation; these are building up, or constructive, processes and require a supply of energy from the sun or the living protoplasm to bring them about. This food is then united with oxygen, thereby releasing this sun-given energy. It is this energy which keeps the plant alive and permits it to grow. This last process is, however, a destructive one as far as food and tissue are concerned and necessitates excretion in order to remove the waste.

The Leaf as a Factory

The factory	Green leaves (or other green tissue).
The work rooms	The cells of palisade and spongy layers.
The machines	Chlorophyll grains and protoplasm
The power	Sunlight.
Materials	Carbon dioxide and soil water.

Supply department	Root hairs, ducts, air spaces, stomates.
Transportation dept.	Ducts, bast tubes, pith rays.
Finished products	Sugar, starch, proteins, tissues.
Waste product	Oxygen.
Hours of work	Manufacturing dept. daylight *only*. Transport and supply depts. day and night.

Comparison of Photosynthesis and Respiration

Photosynthesis	*Respiration*
Constructive process	Destructive process
Food and tissue accumulated	Food and tissue used up
Energy taken in from sun	Energy released
Carbon dioxide taken in	Carbon dioxide given off
Oxygen given off	Oxygen taken in
Complex compounds formed	Simple compounds formed
Produces sugar, starch, etc.	Produces CO_2 and H_2O
Goes on only by day	Goes on day and night
Only in presence of chlorophyll	In all parts

Experiments with Leaves

To show that Leaves (and Stems) turn toward Light. Two thrifty plants are provided, one is placed in a light-tight box, with an opening at one side for light to enter. The other is placed under the same conditions of heat and moisture, but is given light from *all* sides.

The plant in the box will be found to turn toward the light and to grow rapidly in that direction. However, its stem will be weaker and slenderer, its leaves smaller and paler than the one with uniform lighting.

This experiment shows the response that plants make to light, and also the effect of a limited supply of light on their growth. Every time we see the leaves of house plants turning toward the window, we have a similar experiment in heliotropism. The plant kept outside the dark box was used as a check for this experiment.

Not only do plants turn toward light to expose their chlorophyll, but the chlorophyll itself is dependent on light for its formation. When plants are kept in complete darkness the tissues lose their green color. Celery plants are partly covered to produce "blanching" or whitening, which is due to lack of chlorophyll.

Photosynthesis. To Show that Green Plants Produce Starch. Leaves can be taken from active green plants, scalded

From Atkinson.

FIG. 37. Experiment to show that green plants produce starch.
Coleus leaf showing green and white areas, before treatment with iodine. Similar leaf treated with iodine, the starch reaction showing only where the leaf was green.

to kill the protoplasm and release the chlorophyll, and soaked in alcohol to remove the green color. Then, if tested with iodine, a dark blue color is produced, showing that starch was present. The chlorophyll had to be removed so that this blue could be seen. This proves that starch was in the leaf. To prove that it is *made there*, by the action of light on the chlorophyll, requires further experiment.

Sugar was formed before the starch, but it remains in solution and its presence is not so easy to prove.

To show that chlorophyll is necessary, a leaf from a green and white-leaved geranium may be used, as above, when it will be found that little starch is revealed in the white portions.

To show that light is necessary, parts of an active leaf are covered with corks, pinned through, on both sides. After a few days the covered portions will not yield the starch test, while the exposed parts will still do so. Another proof of the same thing is to keep a plant entirely in the dark, as a check experiment, and when it has become pale, test for starch, which will be found lacking. Of course the same kind of plant, under the same conditions, except the light, should be used in this and in the check experiment to be compared with it.

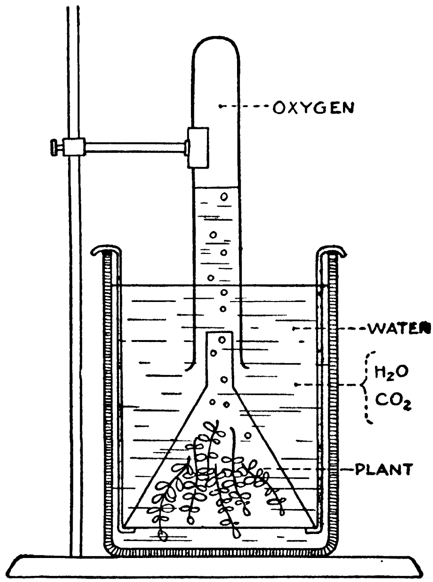


FIG. 38. Experiment to show production of oxygen during photosynthesis.

To Show that Green Plants Produce Oxygen. Oxygen is the waste product of photosynthesis; it is thrown off when sugar and starch are made. It is easier to collect a gas over water, hence a water plant is used for this experiment, but all green plants carry on the same process.

The water plant is submerged in a glass jar under a glass funnel, whose stem is covered by a small test tube, filled with water and inverted. The apparatus is set in the sun and soon bubbles of gas will rise in the funnel and be collected in the tube. These, when tested, prove to be oxygen. If carbon

dioxide be dissolved in the water, the process will go on faster, as carbon dioxide is one of the materials used in photosynthesis, and that in the jar of water is soon exhausted.

Another similar experiment ought to be set up in the dark, so as to prove, again, that light is the source of energy for this very important process.

To prove that the oxygen did not come from the water, another check could be used, in which the apparatus was the same, but no plant was present, in which case no oxygen would be produced.

In experimental work of this kind, the check experiments show almost as much as the ones which actually "work."

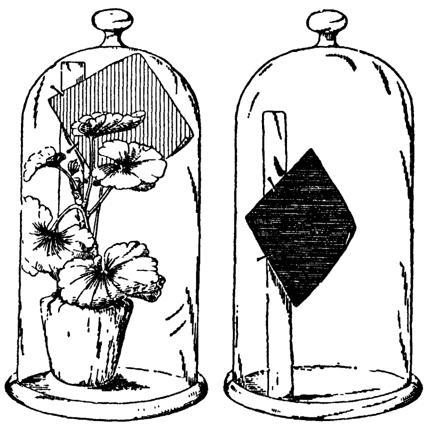


FIG. 39. FIG. 40. *From Atkinson.*

Figure 39 shows plant with pot sealed, but giving off water vapor which has condensed on bell jar.

Figure 40. Left-hand figure, shows plant with sealed pot, giving off water vapor enough to turn the cobalt paper pink within fifteen minutes. The right-hand figure is a check experiment, to show that the moisture in the air would not cause the change in the same time.

Merely stating that the water plant was put under the funnel, and that oxygen was produced, would not prove anything. It would be asked "How do you know that the oxygen came from the plant?" and "How do you know that light had anything to do with the process?" both of which questions are answered by the "checks."

Transpiration. To Show that Plants Pass off Water Vapor. A thrifty cutting is tightly sealed into a bottle of water and placed under a bell jar; another similar bell jar is set alongside containing no plant. Water drops will soon be seen on the inside of the jar with the plant, none on the other. As the bottle was sealed, no water could escape, except such as passed through the leaves of the plant. As the empty jar showed no water, it did not merely condense from the air, hence must have been passed off by the leaves. A potted plant could be used, but the pot and earth surface would have to be wrapped in oiled paper or sheet rubber, to prevent evaporation.

To show which surface of a leaf gives off this water vapor, two watch glasses can be fastened, one on either side of a leaf. More water will be found to condense on the glass fastened to the lower surface, showing that transpiration is more active here. This is as one would expect, since here the stomates are more numerous.

Cobalt paper, which turns pink when moist, can also be fastened to the upper and lower surfaces of a leaf, and will show the same result.

COLLATERAL READING

Plant Relations, Coulter, pp. 148–161; *Botany for Schools*, Atkinson, pp. 90–116; *Elementary Botany*, Atkinson, pp. 53–70; *First Studies in Plant Life*, Atkinson, pp. 121–125; *Lessons in Botany*, Atkinson, pp. 70–72; *Experiments in Plants*, Osterhout, pp. 191–202; *Introduction to Biology*, Bigelow, pp. 55–75; *Plant Life and its Uses*, Coulter, pp. 218–234; *The Great World's Farm*, Gaye, pp. 157–176; *The Story of the Plants*, Allen, pp. 33–53; *Textbook of Botany*, Gray, pp. 85–110.

SUMMARY OF CHAPTER XIII

Process	Where done	Apparatus	Materials	Energy from	Products	Waste
Starch making or photosynthesis	Palisade and spongy cells of leaf, green bark of stem	Chlorophyll and protoplasm	Water Carbon dioxide	Sun, 1 horse power per five square feet	Starch, ¾ oz. per square yard	Oxygen
Digestion	All living parts	Ferments	Starches and proteins rendered soluble	Vitality of plant, process goes on regardless of light	Soluble food stuffs	
Assimilation	All living parts, especially roots, trunk, and branches		Digested starch, nitrates—S. P. taken from soil	Vitality of plant, *i. e.* protoplasm which gets energy by oxidation of C, darkness or light	Protoplasm, tissue, stored proteins, cellulose, lignin, suberin, etc.	
Respiration	All active parts	Stomates and lenticels	O from air, C and H from plant	Chemical affinity of O for H and C, goes on constantly	Energy of plant, little heat	CO_2, *little*, noticeable only at night
Transpiration	Spongy region and air spaces	Stomates regulated by way of protoplasm	Soil water (sap)	Heat, evaporation, root pressure must keep up	Water for starch, NO_3, S, P from proteins, mineral subs. in stems	Water, *much:* stored salts

CHAPTER XIV

FLOWERS: POLLINATION AND FERTILIZATION

Vocabulary

Pollination, transference of pollen from anther to stigma.
Fertilization, union of sperm nucleus and ovule nucleus to form the embryo.
Glands, organs for secretion of any liquid, as nectar glands.
Nectar, a sweet liquid secreted by plants to attract insects. Bees make it into honey; plants do not secrete *honey.*
Learn names of flower parts from the text.

If we refer to the list of life functions it will be seen that we have dealt with all of them except reproduction. All the others have had to do with the life of one individual plant, its food getting, energy production, or waste removal. Now we have to do with a function as important as all the rest, the propagation of new individuals.

The Function of the Flower. In most of the common plants the flower is the organ whose function is reproduction, and, while there are other methods, we shall deal with the commonest one first, since it is found in at least 130,000 different kinds of plants.

The final product of the flower is the seed. To produce the seed, fertilization must take place and to cause fertilization, pollination must precede it. While these terms will be made plain later, we can remember that the flower is provided with means for securing pollination, fertilization, and seed production.

Structure of the Flower. We will take for an example the geranium, either a "single" flowered house species or the common wild geranium, which though different as to genus, is still sufficiently similar for our purpose. As we look at the flower from the rear, or stem side, we will see a row of small, green, leaf-like organs called the *sepals.* This is the *calyx.*

Its function is to protect the flower in the bud condition and to help support the other parts when it opens.

Inside the calyx comes the *corolla* consisting of a row of colored parts called *petals*. These are often for the attraction of insects as we shall see when studying pollination. They may also help to protect the inner and more essential parts.

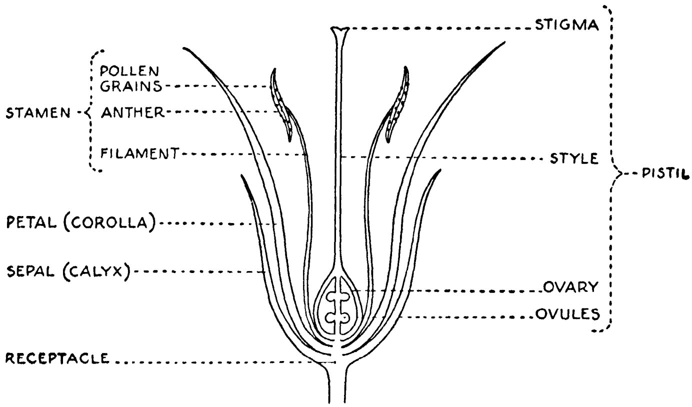


FIG. 41. Diagram showing the parts of a typical flower.

Next inside the corolla we will come to several knobbed, hair-like organs. These are the *stamens*. The knobs at their tops (anthers) are very important, as they produce and scatter a yellow, dust-like substance known as *pollen*. They are placed on these thread-like supports (filaments) so that the pollen will have a better chance to be distributed.

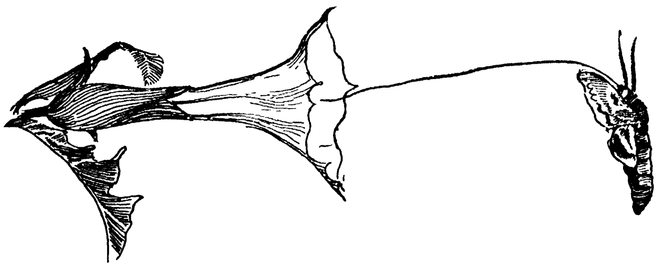
In the very center of the flower is the *pistil* consisting of a sticky knob at the top (stigma) to catch pollen, a slender stalk (style) to support the stigma, and an enlarged portion at the base (ovary) which contains the undeveloped seeds (ovules) and later develops into the fruit.

Pollination. In order that a flower may produce seed, the pollen must be transferred from the anther to the stigma, and usually it must be from the anther of one flower to the stigma of another of the same kind. This transfer of pollen from anther to stigma is called *pollination*. If, as in most

cases, it is between different flowers, it is called *cross pollination* and is the process for which the flower parts are usually adapted. Insects and wind are the two chief agents in pollination and there is no process for which more curious adaptations have been developed. We shall deal first with those that fit the flower for pollination by insects.

Adaptations for Insect Pollination. The bee and the flower are associated in our minds, of course, but it is not so commonly realized that one could not exist without the other, and that many other insects, besides bees, are just as closely concerned.

The insect comes to get its food from the sugary *nectar* which is secreted at the base of the petals; in getting this, its body



After Stevens.

FIG. 42. Hawk-moth about to insert its long "tongue" into the deep flower of the Jimson-weed. The moth is after nectar but will also carry pollen on its hairy body. This will perhaps be shaken off on the pistil of the next Jimson-weed, and so produce cross pollination. Drawing is half natural size.

catches some of the pollen from the stamens which are shaped for this purpose. When the insect visits the next flower some pollen is sure to be rubbed off on the pistil of that flower, and a new supply brushed from the stamens as it crawls out. In this way pollination is accomplished.

The flowers have developed conspicuously colored corolla and attractive odors, in order that the insects may surely find them. They often grow in clusters so as to be easily noticed and visited. After the insect arrives, not only does it find a reward of nectar, but often the flower is shaped to provide a convenient landing place. Colored lines often lead to the nectar glands. Stamens

and pistils hold their anthers and stigmas in just the proper position so that pollen shall be transferred while the insect is obtaining its sweet reward for unintended labors.

Nearly every flower has a slightly different scheme for cross pollination. When we find one with irregular-shaped corolla, we may be almost sure that some special adaptation for insect visitors stands behind the curious shape.

Adaptations for Wind Pollination. Flowers which depend on wind for their pollination are very differently adapted. They produce enormous quantities of pollen, but they have no nectar or odor. Their pistil is usually large to catch the flying pollen, and they secure access to the wind by having very small corollas and by producing their flowers above the leaves of the plant, or before the leaves have developed. Many grasses and sedges and all the evergreen trees have their pollen distributed by the wind. In fact, near large pine forests the yellow pollen fills the air and covers the ground at certain seasons, forming what people call "sulphur showers."

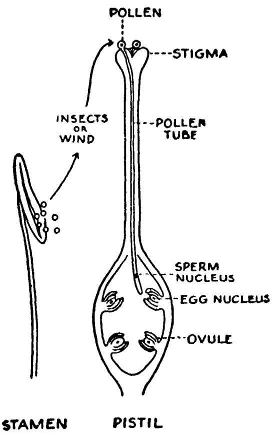


FIG. 43. Diagram showing the process of pollination.

Prevention of Self-Pollination. In general cross pollination seems to produce better seed than self-pollination and some of the most interesting adaptations of flowers have developed to prevent the pollen of a flower from falling upon its own pistil.

Some plants have flowers which produce only stamens or only pistils and not both in the same flower. The two kinds are sometimes on different plants or on different parts of the same plant. This effectually prevents self-pollination and is illustrated in the corn, where the "tassels" are the staminate flowers and the "ears" contain the pistillate ones. Pines, willows, and many others have staminate and pistillate flowers on different individuals.

The shape of the flower in peas, iris, and many others is such that pollen can hardly get to the pistil of the same flower except by accident, but is almost certain to be crossed when they are visited by insects. Often the stamens and pistils mature at different times in the same flower so that when the pollen is ripe, the pistil cannot receive it, or the reverse. This is illustrated by the fig-worts and fire-weeds. Sometimes plants have two different types of flowers one with long stamens and short pistil, and the other with long pistil and short stamens. Such are the primrose and bluet. In this case the insect visitor usually brings pollen from short stamen flowers to those with short pistils and vice versa.

The common blue violet seems to be an exception to the general rule and forms its best seed from self-pollinated flowers. These are not the pretty blue blossoms which we associate with violets. But if we look close to the ground, near the roots of the plant, we will find what might be mistaken for unopened buds. They are really "closed" flowers which never open at all yet produce most of the seed, even though self-pollinated.

Artificial Pollination. Artificial cross pollination is often carried out by plant breeders who wish to develop new species or improve some desirable characteristic in a cultivated plant. The anthers are first removed from the flower buds so that self-pollination cannot take place. The flower is then covered with a paper bag to prevent accidental cross pollination. After the flower has developed the bag is removed and pollen from a plant having the desired characteristic is put upon the stigma, the bag is replaced, and the fruit left to mature. The seeds which develop from this artificial crossing may combine new and valuable qualities not found together in either parent. Such crossing can only be carried out with plants which are nearly related.

Many of our best flowers and fruits are hybrids, either natural or artificial. Many grapes and plums, cereals, crop plants, and garden flowers are results of this process. Luther Burbank of California has become famous for the new plant

species which he has developed, often by this means. The plumcot and primus berry are some of his productions.

Protection of Pollen. Since pollen is absolutely necessary to the plant, it has to be protected from rain and from insects which would eat it and from those which are too small or too smooth-bodied to carry it. Protection against rain and dew is secured by the drooping or closing of the corolla, while unwelcome insect visitors are kept out by hairy or sticky coatings on stem and calyx or on the inside of the corolla.

Essential Organs. Notice that the only organs absolutely needed to produce seeds are the stamens and pistil. Hence they are called the "essential organs." The corolla and calyx have, as their function, the protection of these essential organs and the securing of pollination.

The pollen grain from the anther and the ovule in the ovary are actually the most necessary factors in the process of reproduction and must now be dealt with more completely.

Pollen Structure. The pollen grain is at first a single cell but if transferred to the stigma of a flower of its own kind, it begins to grow, developing into a very long tube which reaches from stigma to ovary, no matter how long that may be. Two sperm or male nuclei are formed and pass down this pollen tube. Their union with the ovule is called fertilization and produces the embryo in the seed.

Ovule Structure. The ovules (undeveloped seeds) are protected inside the ovary and can be reached only by way of the pollen tube from pollen grains on the stigma. They are much larger and more complicated than the pollen grains. Each ovule in the ovary has a protective covering which later becomes the testa of the seed. Within this is the nucleus of the ovule cell which divides into eight cells, two of which form the endosperm and one, the most important, becomes the egg or female cell. As has been said, the pollen tube grows downward through the style till it reaches the place where an ovule is attached to the ovary wall; near this point of attachment is

an opening through the ovule coats, called the micropyle, and through this the pollen tube makes its way till it reaches the egg cell within.

Fertilization. The sperm cell then passes down the pollen tube and unites with the protoplasm of the egg nucleus. This union of the sperm nucleus of the pollen with the egg nucleus of the ovule is called fertilization. The fertilized egg now has the very remarkable power to grow, and from its one cell, to develop the countless numbers which go to make up the embryo within the seed and finally the whole new plant. Notice that in this wonderful process each plant is reduced to a single cell, the sperm or the egg,—that they unite and again form a single cell, and that from this develop the embryo and the whole organism.

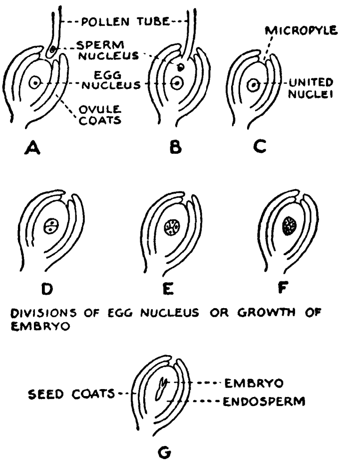


FIG. 44. Diagram showing the process of fertilization. A. Pollen tube entering micropyle with sperm nucleus at lower end. B. Sperm nucleus has passed out of pollen tube, toward egg nucleus. C. Sperm and egg nuclei have united. This is actual fertilization. D, E and F. Stages in growth of embryo, as result of fertilization. G. The matured seed. Embryo will develop no further till germination takes place. Food, unused by growth of embryo may remain as endosperm for use in germination.

Fertilization is essentially the same in both plant and animal so we must think of all living things as having developed from a single fertilized egg cell.

Origin of Seed Parts. Look back at Chapter VI and notice that we have just been studying the origin of all parts mentioned in the structure of the seed: the ovule walls become the testa and tegumen; the opening for the pollen tube is the micropyle; the fertilized egg develops into the embryo, and the endosperm nuclei produce the endosperm.

The embryo may develop to a great extent within the seed and use all the endosperm, or it may develop but little and

leave unused endosperm for the germination process. In either case it was present at one time.

Notice that the seed stage is only a pause in the continuous circle of growth. The parent plants produce the pollen and ovules; these produce sperm and egg; both finally unite. The embryo is formed and grows more or less within the seed, then merely waits till it shall have conditions favorable for continuing its growth to an adult plant, again. In this way the life cycle is completed. The parents die but parts of their actual protoplasm live on, in the new generation.

COLLATERAL READING

Pollination

Cross and Self Fertilization in the Vegetable Kingdom, Darwin; *The Great World's Farm,* Gaye, pp. 208–214; *With the Wild Flowers,* Hardinge, pp. 47–55; *Ten New England Blossoms,* Weed, pp. 1–17, 90–98; *Beauties of Nature,* Lubbock, pp. 117–138; *The Fairy Land of Science,* Buckley, pp. 212–237; *Elementary Studies in Botany,* Coulter, pp. 151–166; *Plant Life and Uses,* Coulter, pp. 301–322; *Natural History of Plants,* Kerner and Oliver, Vol. II, Part 1, pp. 129–283, 426–436, Part 2, 833–840, 862–866; *Experiments in Plants,* Osterhout, pp. 286–311; *Plants and their Children,* Diana, pp. 187–255; *The Living Plant,* Ganong, pp. 303–326; *The Story of Plants,* Allen, pp. 73–135; *Outline of Botany,* Leavitt, pp. 120–127; *Textbook of Botany,* Bessey, p. 421; *Textbook of Botany,* Strasburger, pp. 281–283; *Plant Relations,* Coulter, pp. 123–137; *Introduction to Botany,* Stevens, pp. 166–201; *Plant Structures,* Coulter, p. 181; *Nature and Work of Plants,* McDougal, pp. 149–153; *Lessons in Botany,* Atkinson, pp. 192–193; *Elementary Botany,* Atkinson, pp. 351–367; *Botany for Schools,* Atkinson, pp. 167–181; *Flowers, Fruits and Leaves,* Lubbock, pp. 1–44; *Plant Life,* Step, pp. 35–58; *Wonders of Plant Life,* Herrick, pp. 149–173; *Blossom Hosts, and Insect Guests,* Gibson, entire; *Flowers and their Friends,* pp. 121–133; 231–239; *Fertilization in the Vegetable Kingdom,* Darwin, pp. 356–414.

Fertilization

Botany for Schools, Atkinson, pp. 182–186.

Flower Structure

Plant Structures, Coulter, pp. 218–231; *Lessons with Plants,* Bailey, pp. 131–150; *Botany for Schools,* Atkinson, pp. 140–166; *Plant Life and Uses,* Coulter, pp. 258–300; *Applied Biology,* Bigelow, pp. 196–213.

SUMMARY OF CHAPTER XIV

FLOWERS; POLLINATION; FERTILIZATION

1. **Function of flower.**
   a. Reproduction by seeds.
   b. Providing for
      (1) Pollination.
      (2) Fertilization.

2. **Structure of Flower.**

Parts	Function
Calyx (sepals)	Protection and support
Corolla (petals)	Insect attraction for pollination. Protection of essential organs.
Stamens, Anther Filament	 Production of pollen. Support of anther for pollination.
Pistil, Stigma Style Ovary	 To catch pollen: sticky, sometimes large. To support stigma so as to catch pollen. Contains ovules, forms fruit.

3. **Pollination.**
   (a) Definition.
   (b) Meaning of "cross-pollination."
   (c) Means for pollination.
      (1) Insects (clover, etc.).
         a. Adaptations for insect pollination.
            1. Nectar.
            2. Bright color.
            3. Landing places.
            4. Odor.
            5. Growth in clusters.
            6. Special shapes.
      (2) Wind (pine, corn, grasses, etc.).
         a. Adaptations for wind-pollination.
            1. Flowers high above leaves, not conspicuous.
            2. Petals and sepals small or lacking.
            3. Pistils large and sticky.
            4. Abundant pollen (why?)
            5. No nectar or odor.

(d) Prevention of self-pollination.
  (1) Stamens and pistils in different flowers.
  (2) Shape of flower.
  (3) Stamens and pistils mature at different times.
  (4) Stamens and pistils of different lengths.
(e) Artificial pollination.
(f) Pollen protection.
  (1) From rain.
    a. By closing or drooping of flower.
  (2) From unwelcome insects.
    b. By sticky stems or hairy flowers.

4. Fertilization.

(a) Definition.
  (1) Union of sperm nucleus of pollen with egg nucleus of the ovule.
(b) Pollen.
  (1) Produced by stamen (anther).
  (2) Structure.
    a. One-cell stage.
    b. Three-cell stage.
    c. Pollen tube.
      1. Use.
    d. Sperm cells.
      1. Use.
(c) Ovule (undeveloped seed).
  (1) Produced in the ovary.
  (2) Structure.
    a. Coverings (later become seed coats).
    b. Nucleus (one cell)
      1. Divides into eight cells.
        (a) Two cells form endosperm.
        (b) One cell forms egg cell proper.
(d) Steps in fertilization.
  (1) Pollen tube penetrates mycropyle.
  (2) Sperm nuclei pass down pollen tube.
  (3) Nuclei of sperm and egg unite (fertilization proper).
  (4) Embryo begins to develop.

5. Development of seed parts.

(a) Ovule walls become seed coats.
(b) Opening for pollen tube is the micropyle.
(c) Fertilized egg becomes the embryo.
(d) Endosperm nuclei become the endosperm.
  (1) Endosperm may be used by developing embryo.
  (2) Endosperm may remain to be used in germination.

CHAPTER XV

FRUITS AND THEIR USES

Vocabulary

Matured, fully developed.
Superficial, careless.

While the seeds are developing the ovary grows also and the final result is what we call a fruit. This does not necessarily mean "fruit" in the sense of a fleshy edible product, but applies to the seed-holding organ of any plant. A fruit may be defined as the matured ovary, its contents, and all intimately connected parts. Thus a fruit may consist of a single ovary with only one seed, as in grains, nuts, cherries, or plums, or it may develop from a single ovary which has several seeds, as in pansy, pea, poppy, or apple. On the other hand there are many flowers which have several ovaries. These combine to form compound fruits like the strawberry or raspberry. Fruits may therefore be either dry or fleshy, simple or compound, depending on the character and development of the ovary which formed them.

Types of Fruits. The peach is a good example of a one-celled, simple, fleshy fruit. In it the ovary wall develops two parts, an outer fleshy layer and the hard inner "stone" which encloses the seed. Such a fruit is called a *stone fruit.*

The apple develops from a five-celled ovary which forms the core. Outside of this is a fleshy region, usually bounded by a faint line which is probably the fleshy ovary wall, or may be an enlarged receptacle. Outside of this is the bulk of the apple, which is a greatly thickened calyx, as is indicated by the five tiny sepal tips which persist at the blossom end. Inside these tips the dried stamens and pistil may sometimes be found. A section through an apple shows the outer skin, the calyx layer, the fleshy ovary wall, the hard ovary wall and the seeds at-

tached to the central axis, with their points toward the stem. A fruit of this type is called a *pome* and is represented by the apple, pear, quince, and medlar.

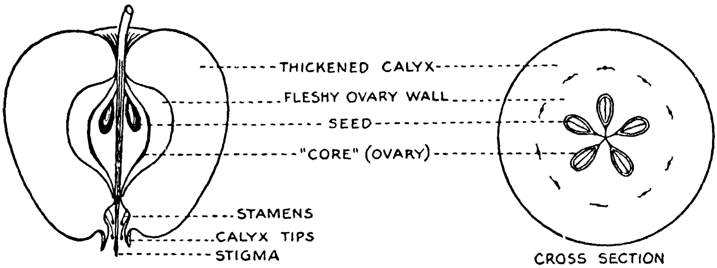


FIG. 45. Structure of a fleshy fruit (Apple). The outer region is probably the greatly thickened calyx, as the persistence of the five calyx tips at the blossom end would indicate. Some botanists consider it the enlarged end of the stem which has carried up the calyx with its growth. The ovary has two walls, the leathery core and the fleshy layer around it. In the cross section, the five seed chambers are shown. Each may have one or two seeds, with their pointed ends toward the stem end of the apple. Faint lines of color sometimes mark the division between the fleshy ovary wall and the rest of the fruit. In the cavity at the blossom end the dried remains of stamens and stigma may sometimes be found. The parts included in the apple are the calyx, ovary and perhaps the thickened end of the stem.

The bean pod is a type of a many-seeded dry fruit, called a *legume*. At the stem end may be found the remains of the calyx lobes. The bulk of the pod is the ovary; the pointed tip

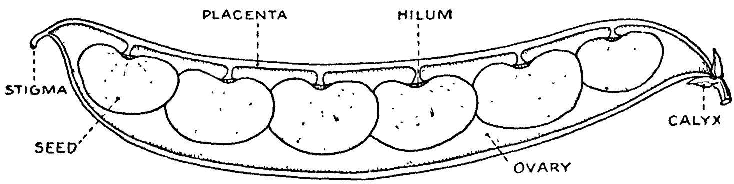


FIG. 46. Structure of a dry fruit (Bean). This fruit consists of the fully developed pistil, the bulk being the enlarged ovary, the style being reduced to the tapering tip, and the stigma usually falling off at maturity. The "string" which we remove in preparing string beans is a duct bundle which brought nourishment to the ovules, with each of which it was connected by way of the hilum;—this point of attachment is the placenta. Remains of sepals sometimes are found at the base of the pod.

is the style, on which the stigma may sometimes be found in young pods, as a tiny knob. The "string" is a vascular bundle bringing nourishment to the growing ovules, which are at-

tached along one side of the pod. Their point of attachment is called the placenta, and the scar left on the seed, when it is removed, is the hilum. The bean fruit thus includes mainly the greatly enlarged ovary and its contents, with the style and possibly the stigma also.

Functions of Fruits. The chief functions of fruits are to protect the ovules and seeds from attack by insects, or fungous spores; to prevent loss of water; and to provide for dispersal. To perform these functions the ovary develops in various ways. Tufts of hair, wings, or hooks may be produced to aid in dispersal. Tough shells or rinds may form for protection as in nuts or lemons. Delicious flesh may envelop the hard inner stone, tempting animals to eat the fruit and discard the seed at a distance from the parent tree. The peach or cherry are examples of this. In addition to the developments of the ovary wall, the calyx may become fleshy and envelop the ovary as in apples and pears. In other cases the end of the stem (receptacle) enlarges and becomes a part of the fruit, as in the case of the strawberry and blackberry.

Methods of Seed Dispersal (See Fig. 47)

By Means of Wind. The *maple* "key" is one of a pair of fruits which separate as they fall. They whirl like a propeller and so fall slowly and are blown to a distance. The heavy end works down in the grass thus giving the seed a chance to germinate.

The *pine seed* (not a fruit) is shaken out of the cone and dispersed in a manner similar to the maple.

The *basswood* has a group of fruits attached to a parachute which causes them to fall slowly and thus scatter, or if they fall on the "crust" in the winter, it will drag them to a distance on the snow.

The *poppy* fruit has a "pepper box" arrangement with many small openings. The stem is stiff and springy and the small heavy seeds are thrown out as the pod whips in the wind.

The *dandelion* and *clematis* both have fruits provided with parachutes of downy hairs which carry them far and wide. This is a common device for dispersal.

By Mechanical Devices. The *pea*, like most of its family, throws out its seeds by the twisting of the pod as it dries.

The *wild geranium* slings out its seeds as the pod splits upward.

The *violet* and *witch hazel* pinch their seeds out as the pods dry and close together.

By Means of Water. The *bladder nut* and *sedge* have life preservers which allow their seeds to float on water. The former may also blow about.

By Hooks or Burrs. *Desmodium* and "*pitch-forks*" have hooks which catch on animals and are thus scattered. This also is a common method of dispersal.

Seed Dispersal. That the ovary wall protects the seeds from insect attack, drought, decay, and weather is plain enough,

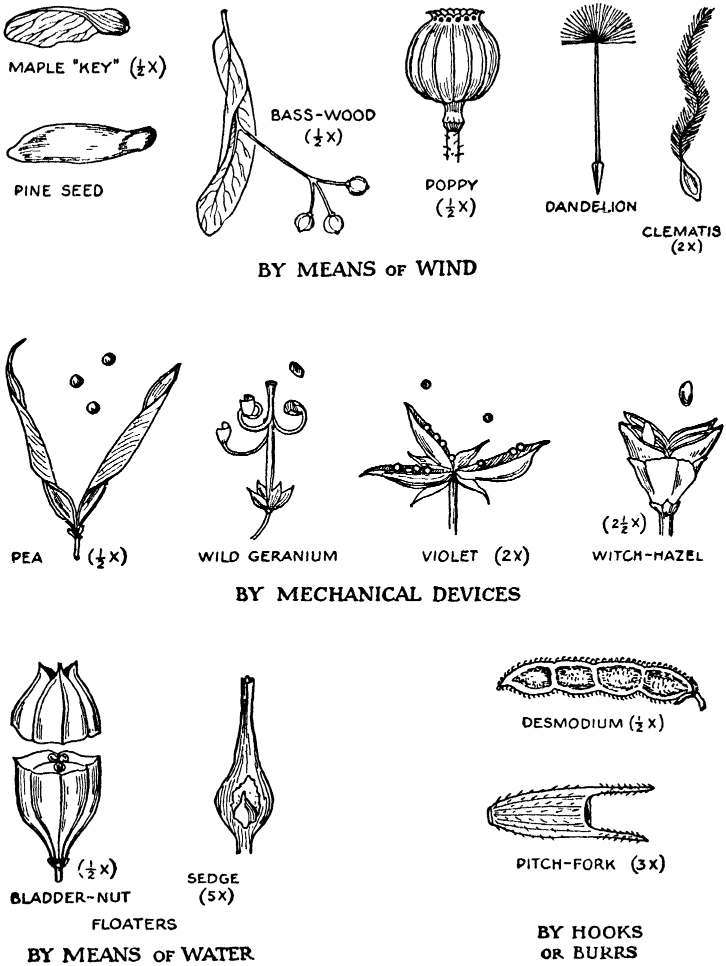
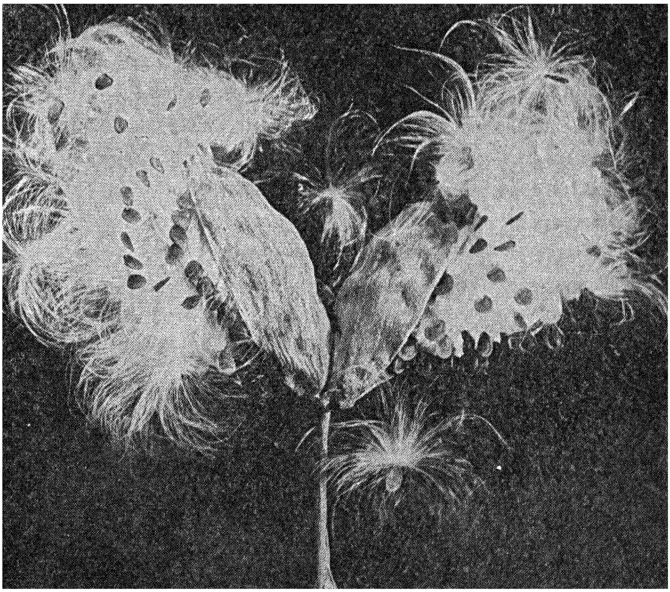


Fig. 47.

but how the other function, dispersal, is accomplished may not be so evident. The most superficial observation of any common plant, such as the dandelion, will reveal two facts: (1) an

enormous number of seeds are produced, and (2) each full-grown plant requires a relatively large amount of room. Evidently, then, the seeds must be scattered if they are to survive, and usually those plants producing most seeds or needing most room best attend to this matter of seed dispersal. There is scarcely a more interesting chapter in biology than this one



From Atkinson.

FIG. 48. Seed dispersal. The seeds of the milkweed have tufts of silky hairs which act as parachutes, carrying them far from the parent plant.

which deals with the wonderful adaptations by which seeds, though having no power of locomotion, still manage to transport themselves long distances and in great numbers. Plants use the wind, water, animals, and various mechanical schemes to scatter their seeds. Sometimes it is the seed by itself which is transported, sometimes the whole fruit, but the end is the same, to get a new place where there shall be space, food, light, and moisture for the development of the waiting embryo.

Adaptations for Wind Dispersal. Adaptations for wind dispersal are found in the tufts of down on thistle and dandelion fruits and milkweed seed, in the wings on the fruits of elm, ash, or maple, or on the seeds of the catalpa or pine.

Adaptations for Dispersal by Animals. Burrs and hooks, as in burdock and "pitchforks," enable the fruits to steal rides on animals and man, and get themselves picked or shaken off at great distances. The delicious flesh of peach or apple, grape, or berry is merely a sort of bribe to reward some animal for carrying off the fruit. The seeds of all such are indigestible and so are discarded far from the parent plant. It is noteworthy that unripe fruits are usually poisonous or bad tasting. Thus they are not eaten before the seed is ready for dispersal.

Dispersal by water. A considerable number of plants secure dispersal by having fruits that float, without absorbing water, and so are carried by rivers or ocean currents to favorable places along the shore. Sedges and coconuts are examples of this type.

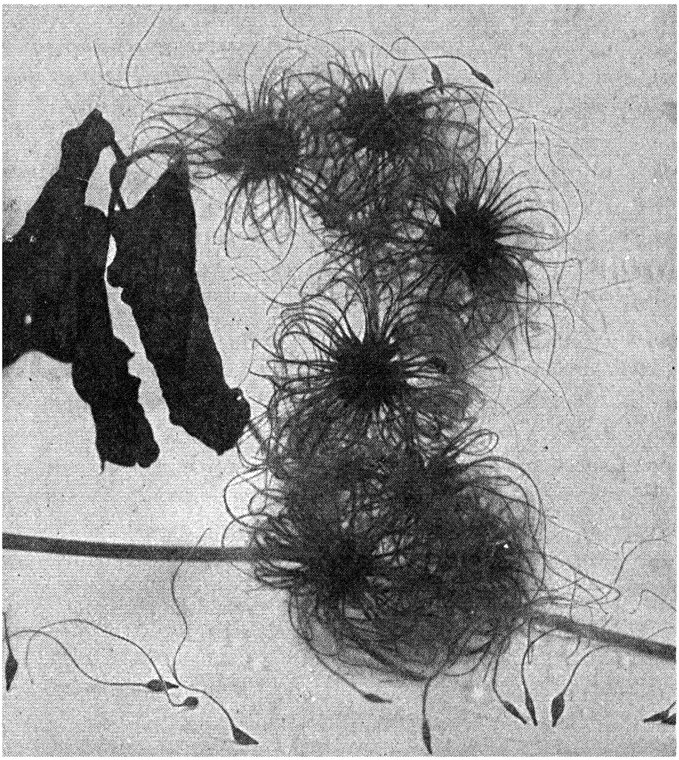
Mechanical Dispersal. Some of the most curious adaptations for seed dispersal are the mechanical devices by which seeds are thrown from the pods for a considerable distance. The touch-me-not, whose pod explodes when ripe; the witch hazel, which pinches the seed between the open ovary walls till it shoots out; the tall stalked mullein and poppy, which whip in the wind and sling their fine heavy seeds far away are examples of this interesting type.

Economic Importance of Fruits. So far as the plant is concerned, the object of the fruit is to secure reproduction by providing the enclosed seeds with protection and transportation. However, man has learned to depend upon fruits for food and other uses, so that they are the most important part of the plant for his purposes.

To begin with, we must remember that the grains, such as wheat, rice, and corn, are *fruits* and not merely seeds as we commonly think. These furnish more food than all other plant parts, combined. Then there are the fleshy fruits—like the apple, orange, grape, and peach—which we use raw, cooked and canned, and from which many other food products are manufactured. From the downy contents of the cotton boll we

obtain that most essential fiber, which nature intended to help in dispersing the seed.

On the other hand, the fruits of some weeds are altogether too efficient in their methods of dispersal, and we have to fight the



From Atkinson.

FIG. 49. Seed dispersal. Each fruit of the clematis has a long feathery tail which adapts it for dispersal by wind.

spread of plants like the dandelion, hawk weed, burdock, and thistle. Some fruits are poisonous, presumably better to protect the seeds, and these occasionally do harm to man; among them may be mentioned the Jimson weed, night-shade, and water hemlock.

COLLATERAL READING

Seed Dispersal, Beal, entire; *Little Wanderers*, Morley, entire; *Plant Relations*, Coulter, pp. 112–122; *Introduction to Botany*, Stevens, pp. 207–217; *Plant Structures*, Coulter, pp. 210–215; *The World's Great Farm*, Gaye, Chaps. 17 and 18; *Textbook of Botany*, Strasburger, pp. 288–291; *Lessons in Botany*, Atkinson, pp. 292–299; *Elementary Botany*, Atkinson, pp. 368–373; *Lessons with Plants*, Bailey, pp. 336–341; *Plants and their Children*, Dana, pp. 50–73; *Botany for Schools*, Atkinson, pp. 198–205; *Flowers, Fruits and Leaves*, Lubbock, pp. 45–96; *Natural History of Plants*, Kerner and Oliver, Vol. II, Part 2, pp. 833–878; *Elementary Studies in Botany*, Coulter, pp. 167–186; *Experiments in Plants*, Osterhout, pp. 312–325; *With the Wild Flowers*, Hardinge, pp. 202–216; *The Story of the Plants*, Allen, pp. 149–161; *The Living Plant*, Ganong, pp. 378–402.

SUMMARY OF CHAPTER XV

FRUITS

1. **Definition.**
2. **Types.**
   - a. Stone fruit (peach).
     - (1) One-celled.
     - (2) Fleshy.
   - b. Pome (apple).
     - (1) Many-celled.
     - (2) Fleshy.
   - c. Grain or nut (corn, pecan)
     - (1) One-seeded.
     - (2) Dry.
   - d. Legume (bean).
     - (1) Many-seeded.
     - (2) Dry.
3. **Functions.**
   - a. Protection.
   - b. Dispersal.
     - (1) Reason for dispersal.
     - (2) Means of dispersal.
       - (a) Wind.
         - 1. Adaptations for wind dispersal.
           - a. Tufts of down (dandelion, thistle).
           - b. Wings (maple, ash, elm).
       - (b) Animals.
         - 1. Adaptations for animal dispersal.
           - a. Burrs (burdock).
           - b. Hooks ("pitchforks").
           - c. Edible flesh (peach).
           - d. Hard or bitter "pits" (Why?)
           - e. Bad tasting when unripe (Why?)
       - (c) Water (sedge, coconut).
       - (d) Mechanical devices.
         - 1. Explosive fruits (touch-me-not).
         - 2. Pinching fruits (witch hazel).
         - 3. Whipping fruits (poppy, mullein).
4. **Economic importance.**
   - a. Propagation.
   - b. Food.
   - c. Fiber.
   - d. Harmful weed seeds.
   - e. Poisonous fruits.

CHAPTER XVI

SPORE-BEARING PLANTS

Vocabulary

Complicated, not simple in structure.
Parasite, plant or animal which obtains nourishment at the expense of another.
Scavengers, destroyers of waste matter.

The majority of plants with which we are familiar obtain food, grow, and reproduce by root, leaf, flower, and fruit, just as we have been learning, but there are a large number of important, but less conspicuous, forms that have no flowers, and so produce no seeds. These flowerless plants reproduce by single cells called *spores* which, by a more or less complicated process, develop into the plant again.

Classification of Spore Plants. The simplest of these flowerless plants are the *algæ*, which may consist of only one cell as in pleurococcus which forms the green coating often seen on stones, bark, and old fences, or they may grow to large, many celled forms, such as the sea weeds, or the green mats of pond scum (Spirogyra) that cover our ponds. The *fungi* are another large group of spore plants which have no chlorophyll and hence have to depend on other plants or animals for organic food. Among them we find mushrooms, puff balls, molds, yeasts, and bacteria. The next group, *lichens*, are really organisms consisting of algæ and fungi living together as one plant and are familiar as the variously colored, flat, scaly forms that grow in patches on rocks and trees. More familiar still are the *mosses* forming the green carpet of the woods, and finally we come to the largest and most complicated of the spore plants, the *ferns* and their relatives, the horse-tails and ground-pines.

While it is not necessary to learn these names or figures, the following table will show you how large and varied the plant kingdom really is and how few we know of its members.

Flowering plants (producing seeds):	
True flowering plants and	130,000 kinds
Pines and their relatives	
Flowerless plants (producing spores)	96,600 kinds
Thallophytes (algæ and fungi):	
Algæ	16,000 kinds
Fungi	55,000 kinds
Bryophytes (mosses and their relatives)	16,500 kinds
Lichens	5,600 kinds
Ferns	3,500 kinds

The Fungi. With the exception of the fungi, all these plants have chlorophyll and so can make their own starch foods; but this particular group has developed the habit of taking its food from other plants or animals, either dead or alive. Organisms which take their food from other living things are called parasites; those that live on dead organic substances are saprophytes. Most fungi belong to this latter group and get much of their food from dead plant or animal tissue, instead of making it themselves, as do the green plants.

Results of Parasitic Habit. When a plant or animal ceases to use an organ that organ degenerates, and the plant or animal loses the ability to use it. So it is with the fungi; they can no longer make their own organic food, and are totally dependent on others for their life. They have to produce millions of spores since only a few can hope to survive.

Many fungi perform a useful function in nature by using dead organic tissue for their food, thus acting as scavengers. They also convert such useless matter into food materials which the higher plants can use again. Fungi that feed on dead organic tissue may be useful as scavengers, but unfortunately this dead tissue may also be needed by man for food. The fungi that attack our stored meats and vegetables cause a great deal of loss and expense.[1]

The fungi bear a peculiar and important relation to other plants and animals, and especially to man. Therefore we shall deal with them as an example of the spore-producing type of plants.

[1] Bacteria are fungi, some of which cause disease, some destroy food stuffs, and others are very useful in many ways.

Examples of Fungi. The *mushrooms* are the largest fungous forms and while some few are edible the majority are useless for food. Many are poisonous, and the shelf-shaped mushrooms found on trees do enormous damage to timber. Just a word of warning at this point: a "toad stool" is merely a name that some people attach to poisonous mushrooms. There is really no such difference. No "rule" or "sign" can be given by which you may distinguish poisonous forms. Their food value is very slight while the poison of the harmful forms is usually fatal. Bearing this in mind there is but one conclusion, either learn to recognize one or two edible kinds and use them *only*, or leave them all severely alone as food.

Courtesy of "Nature Magazine."
FIG. 50. Destroying Angel mushroom, poisonous; note the bulbous base and cup.

Other Fungi. Another class of the fungi includes the *rusts* and *smuts* which attack grains, corn, and other grasses, doing enormous damage to crops. *Mildew* is a common fungus whose chief harm is the causing of rot in potato and similar crops, and destruction of grapes

Courtesy of "Nature Magazine."
FIG. 51. Death Cup mushroom, a poisonous species.

and other fruits. *Molds* are also familiar forms which thrive upon food stuffs, bread, meats, canned fruits, and even wood and paper, if conditions are such that their spores can germinate.

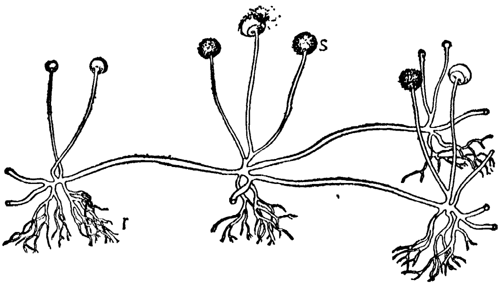
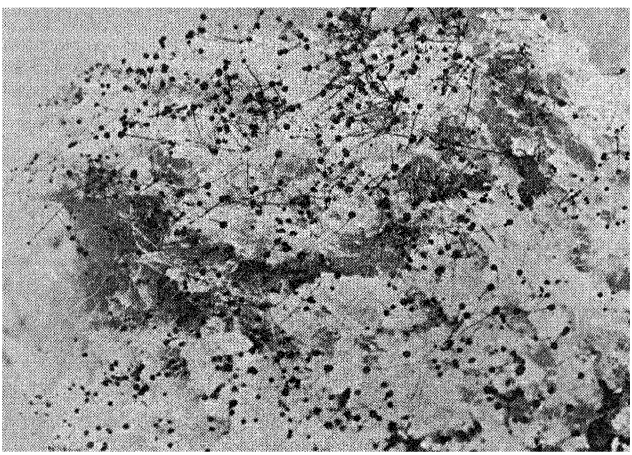


FIG. 52. Structure of the black mold; s, spore cases; r, mycelium for absorption.

The *chestnut blight* is a fungous disease which has practically destroyed the American chestnut in recent years. The *pine blister rust* is doing great damage to the pines. *Wheat rust* causes about $50,000,000 loss annually, and the *potato wart* is a fungous pest which attacks the potato crop. It is estimated that there are 238 kinds of fungi that attack useful plants.

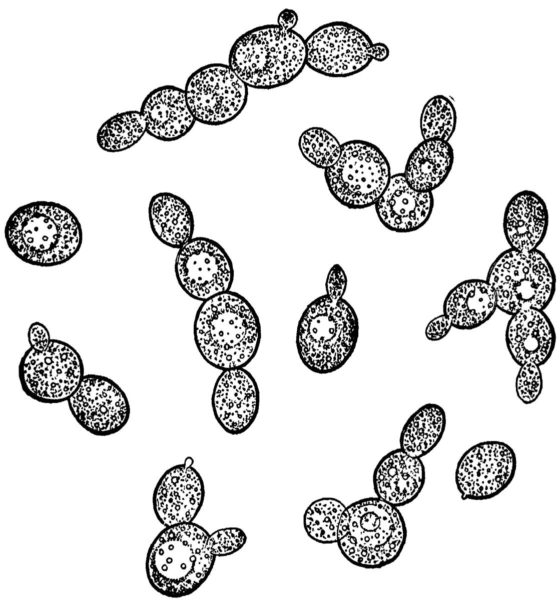


Courtesy of "Nature Magazine."
FIG. 53. Bread Mold.

Bread Mold. One of the commonest fungi is *bread mold.* It appears as a mass of downy threads which develop on the

surface of stale bread. One microscopic spore, under favorable conditions, will soon cause a whole slice of bread to be covered with a fuzzy coating of mold. Looked at with a lens, this coating is seen to be composed of numerous branched threads, called mycelium, which penetrate the bread and take up nourishment, somewhat like roots, though their structure is entirely different. They absorb and digest the food on which they grow, thus causing decay.

When ready to reproduce, tiny upright threads are produced, at the top of which develop round black spore cases filled with



From Sedgwick and Wilson.

FIG. 54. Colonies of budding yeast cells.

dust-like spores. When ripe, these cases open and the spores are scattered. If they fall on suitable food substances in a moist, warm place, each spore may produce mycelium threads and start the plant over again in its life cycle.

Yeast plants are a still simpler class of fungi. We use them so commonly that we hardly realize that they are plants at all.

Yeast, however, is a true one-celled plant, living on dilute sugar solutions which it changes to alcohol. It sets free carbon dioxide gas as a waste product. Thus yeast is used in two very different kinds of industry, the manufacture of alcoholic liquors, where the alcohol is the desired product, and in the making of bread, where the carbon dioxide is required to make the loaf "light" by its expansion. Yeast consists of single oval cells. It reproduces very rapidly if kept warm and moist and supplied with sugar for food. Buds develop on each parent cell and soon become full-sized cells which again reproduce, the process being extremely rapid. A loaf of bread is the product of at least two very different kinds of plants, (1) the complicated wheat plant whose store of starch we make into flour and (2) the simple yeast which helps to make it palatable.

We have left till the last the most important member of the fungi—the *bacteria*. They are of such vast influence, both for good and harm, that the next chapter will be entirely devoted to them.

COLLATERAL READING

Applied Biology, Bigelow, pp. 232–297; *General Biology*, Sedgwick and Wilson, pp. 184–191 (yeast); *The Science of Plant Life*, Transeau, pp. 234–292; *Plant Life and Plant Uses*, Coulter, pp. 360–410; *College Botany*, Atkinson, pp. 137–291.

SUMMARY OF CHAPTER XVI

SPORE PLANTS

1. Kinds of Plants.
- a. Seed plants (corn, bean, etc.)
- b. Spore plants.
  - (1) Algæ (pond scums, seaweeds, etc.)
  - (2) Fungi (mushrooms, toadstools, molds)
  - (3) Lichens (rock and bark patches)
  - (4) Mosses (common mosses)
  - (5) Ferns (common ferns).
  - (6) Fern relatives (horse-tails, ground-pine).

2. Fungi (mushrooms, toadstools, molds)—typical spore plants.
- a. No chlorophyll.
  - (1) Consequence.
- **b. Parasitic or saprophytic habit.**

(1) Result to plant itself.
 (a) Degeneration.
 (b) Dependence.
(2) Result to other organisms.
 (a) Harm to hosts.
 (b) Destruction of food.
 (c) Value as scavengers.

c. Examples.
(1) Mushrooms.
 (a) Some edible, cf. "toadstools."
 (b) Some poisonous.
 (c) Harmful to timber, etc.
(2) Mildews.
 (a) Cause rot in potato, etc.
(3) Molds.
 (a) Attack bread, meats, cheese, etc.
 (b) Structure of mycelium.
 (c) Method of reproduction.
(4) Yeasts.
 (a) Structure.
  1. Oval cells.
 (b) Growth.
  1. By budding.
  2. Conditions for growth.
   a. Moisture.
   b. Warmth.
   c. Food.
 (c) Food.
  1. Sugars.
 (d) Products.
  1. Alcohol.
  2. Carbon dioxide.
 (e) Uses.
  1. Bread.
  2. Beer.

CHAPTER XVII

BACTERIA

Vocabulary

Sterilized, treated so as to kill all germs, either by heat or chemicals.
Culture medium, a substance prepared for growth of bacteria.
Peptone, soluble form of protein.
Inoculation, intentional infection with germs.
Immunity, a condition in which the body is not affected by bacterial attack.

Bacteria are very minute, one-celled, fungous plants. There are many kinds but they are sometimes classified into three groups according to their shape.

1. Coccus forms—round.
2. Bacillus forms—oblong.
3. Spirillum—spiral and curved.

Bacteria that live in the tissues of living plants or animals are called parasites; those that live in dead organic matter are saprophytes. Some of the former cause disease; the latter often cause decay of food stuffs, but on the other hand there are many useful forms in both groups.

Do not forget that certain one-celled, parasitic *animal* forms also cause disease so that when we speak of the germ or microbe, it may mean either a plant or animal parasite, but when bacteria are mentioned, only the plant forms are included. Another point to bear in mind is that not all bacteria are harmful nor are all infectious diseases due to bacteria.

Bacteria are very small, one ten thousandth to one fifty thousandth of an inch in diameter. Some are so minute that they can neither be caught by a filter nor seen by a microscope.

Reproduction. Bacteria, since they have but one cell, absorb food and excrete waste directly. Under favorable conditions of food supply, temperature, and moisture, they reproduce with enormous rapidity, so that one of these mi-

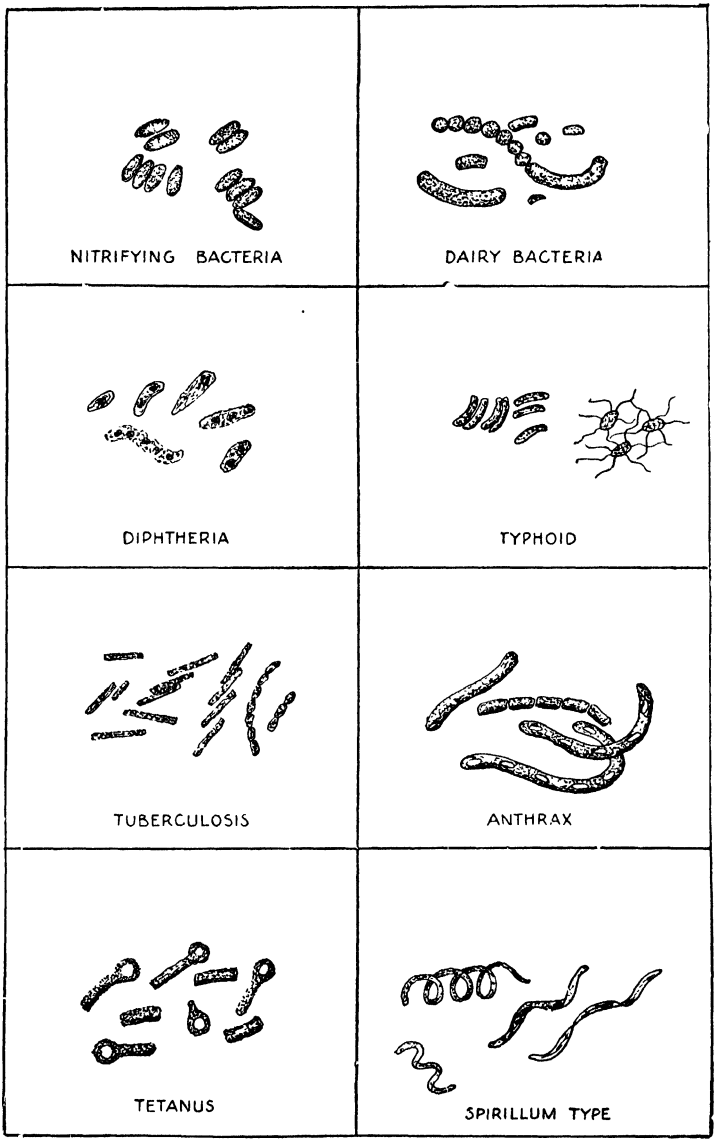


FIG. 55. Some forms of useful and harmful bacteria. (Greatly enlarged).

croscopic cells would, if unchecked, produce a mass of bacteria weighing 7000 tons in three days. Fortunately this rate is never maintained because the food supply soon becomes exhausted, or their own excreted waste matters check their rapid growth. The tuberculosis bacterium divides every thirty minutes; compute the possible number produced per day.

Occurrence. Bacteria are found almost everywhere in air, water, soil, food, inside plant and animal bodies whether dead or alive, wherever they can find food and suitable living conditions. It is fortunate that most of this host of one-celled neighbors are either harmless or useful.

The study of bacteria is called bacteriology. It is a science in itself. The methods used in its study are interesting.

Sterilization. In the first place all dishes and apparatus used are *sterilized;* that is, they are heated or treated with chemicals to kill any bacteria that might come from the air or water.

Making the "Medium." Then a "culture medium" is made from some jelly-like substances such as gelatin or agar, with which beef extract or some similar food is mixed and often peptone and soda are added to make it easier for the bacteria to get their nourishment.

Inoculation. This culture medium is put in sterile dishes and again sterilized several times by heat to kill any bacteria that might be present; the dishes are then covered to keep other bacteria from getting in. Now we are ready for the next step called exposure, or *inoculation* of the cultures. This is done by pouring upon the surface of the culture, a small amount of the milk or water to be tested, or by exposure to the air in the room where the bacteria are to be studied. Touching with the fingers, exposure to dust, and various other means will permit access of bacteria if any be present.

Growth of Cultures. After exposure, the dishes are again covered and set in a warm place for a few hours. We know that the culture medium was sterile, *i. e.*, had no bacteria in it, and we know that conditions favorable to growth are provided.

As a result if any bacteria have been brought in contact with the culture they soon multiply so greatly that a spot or colony develops on the gelatin.

Pure Cultures. Thus the number and kind of bacteria to be found in the substance tested can be determined. Other gelatin can be inoculated from some *one kind* of colony forming a *pure culture,* so that further study can be made and slides can be prepared for use under the microscope.

When our mothers "put up" fruits or vegetables at home, they go through the first part of this same process. They put the jars, covers, and rubbers, in boiling water, which sterilizes them. Then they fill them while still hot with the fruit, which has been sterlized by cooking; and finally they seal the jars to keep any other bacteria from getting in and causing the contents to ferment or "work."

Useful Forms of Bacteria. Do not forget that bacteria do not always mean disease, for as a matter of fact, there are many kinds, without which we could not live. If we pull up a clover plant, there are usually found attached to its roots, numerous small round bunches, called *tubercles.* These are the homes of millions of bacteria which have the ability to take the free nitrogen of the air and combine it into soil compounds which other plants can then use. These nitrogen compounds are absolutely essential to life. No other plant forms can manufacture them from the air. Therefore we see how important these bacteria are in keeping up the fertility of the soil. Nitrifying bacteria are found on the roots of all members of the clover family, such as peas, beans, and alfalfa. It had long been known that plowing under a crop of clover made the soil better for the other crops, but the reason was not understood till the nitrifying bacteria were studied.

Other helpful bacteria are those which, like fungi, aid in decay and therefore act as scavengers, removing harmful waste, and returning it to the soil as plant foods. This process is utilized in sewage disposal systems, where certain bacteria act on the city's sewage—changing it to an odorless and valuable fertilizer instead of a dangerous and expensive waste product.

The souring of milk, the making of butter and cheese, the "ripening" of meats, and the fermentation of vinegar, sauer kraut, and ensilage, are some food processes in which bacteria are indispensable. The separation of hemp and flax fiber from the rest of the plant and several steps in the tanning of leather, curing tobacco, and preparing sponges, are other processes which depend on bacteria.

Harmful Bacteria. On the other hand, tuberculosis, which causes one-seventh of all the deaths in the world, is due to the attack of a bacterium. At least fifty per cent of all deaths are due to this and other bacterial diseases, of which the following is a partial list:

tuberculosis	pneumonia	anthrax
erysipelas	ptomaine poisoning	some cattle fevers
leprosy	typhoid fever	grippe and colds
diphtheria	some eye diseases	lockjaw (tetanus)
tooth decay	whooping cough	cholera

Often when bacteria attack nitrogenous foods, poisonous substances, called *ptomaines*, are produced. These sometimes cause illness or death when such food is eaten. Some serious plant diseases or "blights" are caused by bacteria and result in great crop losses. The connection between bacteria and disease was discovered by Pasteur during researches along this line.

Defences against Bacteria. With this formidable list in view, it is evident that we ought to know how to prevent these bacteria from attacking our bodies and how to combat and destroy them when they obtain a foothold in our systems.

Skin. Our first line of defence against these ever-present enemies is our skin, and the mucous membranes which line the inside of the body. If they are clean, whole, and healthy, few bacteria can get inside our defences.

Natural Resistance. If they break through this outer breastwork, the bacteria have to face the second line of defence, which is the natural resistance of a healthy body to any harmful invader. This second line is defended by the white corpuscles in the blood, which actually devour some of the disease germs, and also by antitoxins, which overcome the poisons

made by the bacteria, and which are produced in the blood by the presence of the bacteria themselves. Thus the attack tends to produce a defence against itself, if the body be healthy. This natural resistance to disease is called *natural immunity,* and constantly protects us from germs of whose presence we are entirely unconscious.

To provide conditions favorable to resist disease it is evident then that general good health is essential, aided by cleanliness, pure and abundant food, light, air, and whatever will keep each cell of our body keyed up to repel the invader before his rapid increase gives him the advantage. We know how often when the body is "run down," diseases are contracted, which would otherwise be fought off without our knowing that the bacteria had attacked us. How often a "mere cold" develops into some serious ailment, because the cold, though perhaps not regarded as serious, lowers the resisting power of the body and then bacteria find entrance and overcome our physiological garrison.

The resisting power of the body is also greatly affected by the state of one's mind. Fear of infection invites infection by lowering the vitality. Worry, anger, discontent, or any similar emotions all tend to lower the fighting strength of our bodies and ought to be avoided.

Even when they do not actually permit the germs to overcome our resistance, such feelings do real harm to the body. We cannot properly digest our food when angry or worried; we cannot carry on any of our bodily functions at their best unless the mind also is in a healthy condition. Solomon justified his reputation for wisdom when he said, "A merry heart doeth good like a medicine, but a broken spirit drieth the bones."

Defence by Antitoxins. In case the bacteria do find lodgment in our bodies, there is usually a period of some days between the time of exposure and the actual illness: this period of incubation is the time in which the bacteria are overcoming the body's first resistance and multiplying sufficiently to gain the advantage. Then the colonies of bacteria develop in some organ,—as when diphtheria bacteria attack the throat. The throat is not the

only portion harmed, for the bacteria also secrete a poison (toxin) which causes more serious trouble to other organs of the body. If the patient recovers it is because his body has been able to gradually increase the amount of *antitoxin* in his system and so overcome the poisons produced by the bacteria which are causing the disease.

White Corpuscles. The lymph glands in various parts of the body produce white corpuscles for the blood. If the body is in good condition at the time of disease attack, they greatly increase the number of these defenders. These corpuscles are able to actually "eat up" the bacteria or else carry them back to the lymph glands where they are destroyed.

Opsonins are chemical substances in the blood whose function is not thoroughly understood, but which have to do with combating the attack of disease germs, by making them more susceptible to the white corpuscles. It seems as if the opsonin in the blood can be increased by the injection of dead germs, and this method is sometimes used to produce immunity to certain diseases.

Acquired Immunity. In some diseases, it appears that the fact of having had the attack and successfully overcoming it, had provided the body with such ability to supply that particular antitoxin that the person seldom has the disease again, as for example in the case of measles and whooping cough. The body has been trained, as it were, to oppose that kind of attack and this is called a condition of "acquired immunity."

Vaccination. From this it follows that if one has a mild attack of a serious disease, he may develop sufficient antitoxin strength to oppose the dangerous form, somewhat as a sham battle prepares the soldier to protect himself in the real engagement. This fact is the basis of vaccination which is the inoculation of a well person with a mild form of smallpox, by which he becomes able to resist the attack of this terrible disease. (Smallpox may be due to a one-celled animal germ, not a bacterium.) In a similar way protection is obtained against typhoid fever and hydrophobia. Weak doses of the toxins of these diseases are administered, so that the body gradually increases its an-

titoxin defences and becomes immune to fatal attack. Some people oppose vaccination because when improperly performed, other germs are introduced and serious illness follows but this is a very rare occurrence. Before vaccination was practiced 95 per cent of all people had smallpox, thousands died and all were scarred for life. Then it was one of the plagues of the world, whereas it is now a rare disease.

Typhoid Vaccination. Another disease which can be similarly prevented is typhoid fever. Each year over 100,000 people in the United States and Canada have this disease and about 10,000 die. Those who recover are sick for an average of about eight weeks. This is a tremendous loss in work and wages, to say nothing of the suffering and death. And typhoid fever is a preventable disease and should be stamped out.

To accomplish this, the first thing to do is to be vaccinated against typhoid. Typhoid vaccine is made from dead germs and is injected under the skin of the arm. A slight redness soon appears, remaining for a few days and in some cases accompanied by mild headache. After this simple treatment one is immune to typhoid for several years.

In our Civil War typhoid was one of the worst diseases; in the Spanish-American War nearly 5000 soldiers died of typhoid while only 300 were killed in action. In the World War, on the other hand, all our soldiers and sailors were given the anti-typhoid treatment and as a result the disease was practically unknown.

In addition to vaccination, proper care of those who are sick, disinfection of all wastes from typhoid patients, and suppression of flies which may carry the germs, will prevent its spread from those already ill. Exposure can be avoided by use of pure water, pasteurized milk, and clean foods, by screening food and privies against flies, by proper disposal of sewage, and by the destruction of flies and their breeding places. Infection can be prevented, even if one is exposed, by the general practice of anti-typhoid vaccination.

Antitoxins. Another method of helping our bodies to repel germ attack is by administration of the antitoxin directly. In

vaccination the body learns to make its own, but there are cases where a patient is too weak to do this and the actual antitoxin is used. This is especially true in treatment of diphtheria. This antitoxin is obtained from horses, which have acquired immunity by having been inoculated with frequent doses of the diphtheria toxin, till their blood has an excess of antitoxin. This may then be drawn off, prepared, and injected into the system of the patient early in the attack, thus supplying more antitoxin than the patient might be able to produce in his own cells even after days of illness, if at all.

Before the introduction of antitoxin treatment, half of those who caught diphtheria died of this terrible disease and the pitiful part of it was that so many were children. With the general use of antitoxin, nine out of every ten get well. But even with this improvement 1700 persons died from diphtheria in New York State during 1921.

Toxin-antitoxin Treatment. By means of a more recent method known as the "toxin-antitoxin" immunization, it is possible to greatly reduce this death rate or even to wipe out the disease completely.

The antitoxin used to *cure* diphtheria merely protects the patient for about three weeks. Toxin-antitoxin protects for years or perhaps for life and a person treated with it will not contract the disease. If every child between six months and ten years of age could have this treatment, it would be saved from the danger of one of childhood's worst illnesses and in the end diphtheria would be a thing of the past.

Toxin-antitoxin is a sterile serum, injected into the arm once a week for three treatments. It makes the patient as safe from diphtheria as vaccination does from smallpox. In the very young children there is little if any reaction; in older patients there may be occasional results severe enough to keep a child out of school for a day. What a small price to pay for protection from such a danger!

The older antitoxin treatment was used as a cure for those already having diphtheria; toxin-antitoxin is a sure prevention from having it, and is thus much the better method. Since

diphtheria is peculiarly a disease of young children, the treatment should be administered long before they reach school age if complete protection is to be achieved.

The Schick Test. Some persons are naturally immune to diphtheria, that is, they already have the antitoxin in their blood, and do not need the treatment. A simple method has been developed to tell whether an individual will take the disease if exposed to it. This is known as the Shick test.

It consists in injecting one drop of a special solution into the arm of the person to be tested. If the person is liable to have diphtheria, a red spot will appear at the point of injection; if he is already immune, no spot appears. In either case no sickness follows and the test does not hurt as much as a mosquito bite. The Schick test may also be used after treatment with toxin-antitoxin, to find out if immunity is complete. By this means it is possible to tell who need to take the toxin-antitoxin treatment, and if the testing and treatment are fully carried out, diphtheria, once the scourge of childhood, can be conquered.

Tetanus. Another dreadful disease which is successfully treated in this way is tetanus or lockjaw. This is a frequent result of wounds in which dirt gains entrance, such as Fourth of July pistol injuries and cuts on the feet, which are apt to be infected from the soil. It is not the fact that the nail is *rusty* which makes it dangerous to step on, but that a rusty nail generally is a dirty nail, and may infect with disease.

Antiseptics. Other means of destroying bacteria are by the use of *antiseptics* and *disinfectants* which are chemical substances that destroy or hinder the growth of disease germs. Some valuable antiseptics which should be used, even in small wounds, are iodine, hydrogen peroxide, alcohol, ichthyol ointment, 4 per cent solution of carbolic acid, or 10 per cent solution of potassium permanganate. Boric acid, camphor, thymol, and even common salt are useful in some cases.

Many antiseptic soaps, throat washes, and tooth pastes are advertised: some are good, others make claims which they do

not fulfill. The best plan is to consult your doctor before placing confidence in any of them. Any antiseptic powerful enough to destroy germs would be likely to harm the tissues also.

Disinfectants are chemicals used to kill germs outside the body, as in case of clothing, utensils, bedding, and rooms that have been occupied by persons ill with infectious diseases. Bichloride of mercury, a dangerous poison, is valuable for disinfecting the hands or washing woodwork; *dilute* carbolic acid may be used for the hands, clothing, or bedding. Formaldehyde solution may be similarly used, though sometimes injurious to the skin; several coal tar products such as cresol, lysol, cresoline, etc., are said to be as efficient as carbolic acid, and less dangerous. For outdoor disinfection of cesspools, garbage cans, or privies, chloride of lime or freshly prepared milk of lime may be used, the former being especially useful in typhoid fever.

To disinfect a room following infectious disease, it should be tightly closed and thoroughly fumigated. Then the room should be freely aired and exposed to sunlight, the woodwork and plain furniture scrubbed with soap and water, and repainted or repapered if the time of possible infection has been long. Further disinfection by washing floor and woodwork with bichloride of mercury (1–1000) may be advisable in some cases. Disinfection by gases (fumigation) is usually done with formaldehyde or sulphur dioxide.

For this purpose formaldehyde gas is best and may be prepared by burning a formalin candle, boiling a strong solution of formalin, or by adding permanganate of potash crystals to the solution in the proportion of one-half pound of crystals to each pint of formaldehyde. While not so efficient, and also likely to bleach colored furniture, burning sulphur produces a gas which is a useful disinfectant. One or the other of these substances should always be used in rooms where an infectious disease has occurred. Most germs, both bacteria and animal forms, are killed at boiling temperature. Drying checks their growth and direct sunlight destroys them rapidly. In fact,

direct sunshine through *open* windows is one of nature's best disinfectants. Germs thrive in darkness, both because a dark room is often a dirty room and also because light actually kills the organisms. This is one of the reasons for outdoor treatment of certain diseases. Thorough disinfection is an important process and should be supervised by a doctor or nurse if possible.

Quarantine. During the progress of any infectious disease, or when there is a chance that one has been exposed to such infection, the health officers usually restrict access to the house or sick room, except for those actually in charge of the patient, and these persons are forbidden to come in contact with those outside. Notices are posted and people are forbidden to visit the sick room lest they carry the disease to others.

Quarantine is often inconvenient and sometimes people try to evade its restrictions. This is very wrong, for it is not only breaking a law and so making one liable for civil punishment, but it is endangering the health and perhaps the lives of the whole community. Strict quarantine regulations have done much to help control many infectious diseases and should always be obeyed to the letter.

Food preservation. When we cook our foods, we not only make them more digestible and attractive, but sterilize them as well. Milk may be freed of the most dangerous bacteria by pasteurization, which means heating to a temperature of from 140 to 150° F. for a period of 30 minutes. After pasteurizing it must be quickly cooled and kept closed and cool, or other germs will find entrance.

This brings us to another way in which bacteria do harm to man: they attack his foods, causing them to sour, ferment, or decay. Cooking and canning are two ways which have been mentioned of preserving food from bacteria. Meats are protected by canning, cold storage, salting, smoking, pickling, etc.; fruits and vegetables may be canned, dried, or pickled in vinegar and spices which are really antiseptics. Other more active antiseptics have been used to preserve foods, such as borax, formalin, salicylic acid, and benzoate of soda, but, while

they kill the bacteria, they also harm the person using the foods, and so have mostly been forbidden by law.

Development of Bacteriology. Our knowledge of the action of bacteria dates back only about fifty years, but during this time great headway has been made in their control. Pasteur discovered the relation of bacteria to fermentation about 1860, but it was not until 1880 that their connection with human disease was established. Pasteur's great work against rabies—mad dog poison—was done about 1885 and now only one per cent of the victims die, instead of practically every one, as formerly. In 1894 Von Behring and Roux developed the antitoxin for diphtheria. In the United States, deaths from this cause have decreased from 15 to 2 per 10,000 of population—in fact 98 per cent will recover if treated within two days. In similar ways we are learning to control typhoid fever, tetanus, influenza, and pneumonia. Our knowledge of the means of transmission of disease has led to *preventive* measures even more efficient in preserving human life.

Another result of modern investigation is the cheering fact that germ disease is seldom if ever hereditary. You may inherit low resistance to germ attack, but if precautions are taken to increase this resistance and avoid infection, you need not suffer from the disease.

COMPARISON OF VACCINATION AND ANTITOXIN TREATMENT

	Vaccination	Antitoxin treatment
Method	Mild or dead germs introduced into body	Serum of blood from immune animal introduced into body
Result	Body reacts and forms its own antitoxins	Antitoxins directly supplied
Duration	Immunity develops slowly but persists longer	Immunity provided at once but for only the one case
Diseases treated	Smallpox Typhoid fever Rabies	Diphtheria Tetanus Meningitis

Comparison of Pasteurizing and Boiling Milk

	Boiling	Pasteurizing
Temperature	212 deg.	140–150 deg. (30 min.) or 160–165 deg. (1 min.)
Effect on bacteria	All killed, both harmful and useful	Most harmful ones killed Useful ones unharmed
Effect on taste	Changed Less palatable	Unchanged
Effect on food value	Much reduced Less digestible	Unchanged, except vitamines

Germ Attack and Control

Point of Attack	Disease caused	Means of control
Food via digestive organs	Typhoid Cholera Dysentery Tuberculosis	Cook foods, destroy flies Secure pure water supplies Pasteurize milk, keep food cold and clean
Air via lungs	Tuberculosis Pneumonia Probably measles, mumps, and whooping cough	Avoid dust, check "colds" Anti-spitting laws Quarantine laws, avoid contact with sick Good food, sleep, general health
Skin via wounds	Blood poisoning Tetanus Pus infections	Cleanliness Use of antiseptics and disinfectants Protect from further bacterial attack
Foods or skin via insect transmission	Typhoid	Destroy breeding places of flies Cleanliness, screens, etc. See Chapter XXV on "Insects and Disease"

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17, 34, 41 to 49; *Introduction to Biology*, Bigelow, pp. 256–279; *Applied Biology*, Bigelow, pp. 276–297, 554–560; *Human Body and Health*, Davidson, pp. 46–53; *Principles of Health Control*, Walters, pp. 218–346; *General Physiology*, Eddy, pp. 493–503; *The Human Mechanism*, Hough and Sedgwick, pp. 463–504; *Plants and their Uses*, Sargent, pp. 492–495; *The Rat Pest*, Geographic Magazine, July, 1917; *Scientific Features of Modern Medicine*, Lee, pp. 64–79; *High School Physiology*, Hewes, pp. 265–275; *Experiments in Plants*, Osterhout, pp. 361–408; *Introduction to Botany*, Stevens, pp. 256–263; *Nature Study and Life*, Hodge, pp. 457–477; *Scientific Features of Modern Medicine*, Lee, pp. 86–109; *Community Hygiene*, Hutchinson, pp. 233–247; *Handbook of Health*, Hutchinson, pp. 286–313; *Immune Sera*, Bolduan and Koopman, look through; *Infection and Immunity*, Sternberg, look through; *General Biology*, Sedgwick and Wilson, pp. 192–201.

SUMMARY OF CHAPTER XVII

BACTERIA

1. Definition.

2. Distinction between bacteria and "germs."

3. Kinds.

- a. Coccus.
- b. Bacillus.
- c. Spirillum.

4. Characteristics.

- a. Size.
- b. Rate of reproduction.
  - (1) Reason it is limited.
- c. Favorable conditions.
  - (1) Food.
  - (2) Moisture.
  - (3) Warmth.
- d. Occurrence.

5. Methods of study.

- a. Sterilization of apparatus.
- b. Making of "culture medium" (a sterile, moist food supply)
- c. Inoculation with forms to be studied.
- d. Growth of bacterial "colonies" on the medium.
- e. Selection of one kind of colony, making a "pure culture."

(Explain precautions taken in canning fruits.)

6. Useful forms of bacteria.

- a. Nitrogen fixers on clover roots.
- b. Scavengers and decay producers.

c. Forms necessary in following processes.
   (1) Souring of milk, making of cheese.
   (2) Fermentation of alcohol, vinegar, etc.
   (3) Tanning leather.
   (4) Preparing hemp and flax.

7. Harmful forms of bacteria.

a. Those causing disease.
b. Those causing food decay.
c. Plant blights.

8. Natural defences against bacteria, etc.

a. Skin and mucous membranes (clean, whole, and healthy).
b. Natural bodily resistance.
   (1) General good health.
   (2) White corpuscles (destroy germs).
   (3) Antitoxins (oppose bacterial poisons).
   (4) Opsonins.
   (5) Healthy state of mind.

9. Stages in bacterial attack.

a. Incubation (overcoming bodily resistance).
b. Rapid growth of bacteria.
c. Secretion of toxins by bacteria.
d. Secretion of antitoxins by blood.
e. Struggle between body and bacteria.
f. Acquired immunity in some cases.

10. Artificial protection.

a. Vaccination.
   (1) Body resists mild attack, makes own antitoxins.
   (2) Anti-smallpox vaccination.
   (3) Anti-typhoid vaccination.
b. Antitoxin treatment (diphtheria and tetanus).
   (1) Antitoxins developed in other animals (horse).
   (2) Directly administered where body is not able to make its own
c. Toxin-antitoxin treatment (diphtheria).
   (1) Schick test.

11. Germicides (germ killers).

a. Antiseptics (used mainly in contact with body).
   (1) Hydrogen peroxide.
   (2) Carbolic acid, 4%
   (3) Boric acid.
   (4) Camphor.
   (5) Alcohol.
   (6) Ichthyol.
   (7) Potassium permanganate, 10%
   (8) Thymol.
   (9) Salt.

b. Disinfectants (used mainly outside the body).
   (1) Bichloride of mercury (furniture, hands).
   (2) Carbolic acid, 4% (clothing, hands, etc.).
   (3) Formaldehyde (rooms, clothing).
   (4) Creosol, lysol, etc. (clothing, etc., as directed).
   (5) Chloride of lime (garbage, refuse, etc.).
c. Other agencies which kill germs.
   (1) Heat.
      (a) Boiling and cooking.
      (b) Pasteurizing.
         (1) Heat to 140–150 degrees.
         (2) Cool quickly.
         (3) Exclude other bacteria.
         (4) Kills most harmful bacteria.
   (2) Sunlight.
   (3) Dry conditions (hinder development).

12. To disinfect a room.

a. Fumigate.
   (1) Formaldehyde.
   (2) Formaldehyde and potassium permanganate.
   (3) Burning sulphur (danger of bleaching).
b. Disinfect furniture and bedding (see above).
c. Clean all woodwork with soap and water.
d. Refinish the walls if possible.

13. Development of bacteriology.

a. Pasteur, 1860–1880.
b. Von Behring, 1894, diphtheria.
c. Roux, 1894, diphtheria.

CHAPTER XVIII

PROTOZOA

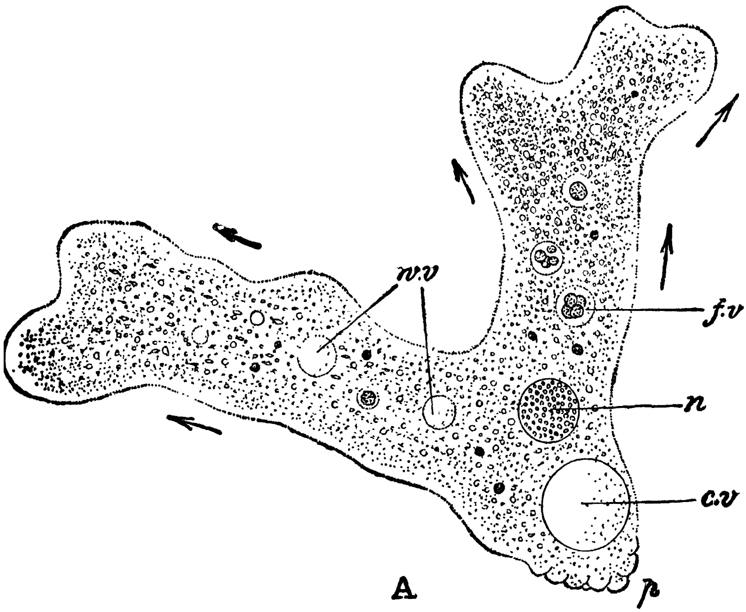
Vocabulary

Protozoa, "first animals," that is, simplest in structure: one-celled.
Microscopic, minute, so small as to be seen only with microscope.
Fission, reproduction by division into two parts.
Conjugation, reproduction by union of parts of the nucleus.
Stagnant, not flowing, as applied to water.
Vacuoles, bubble-like cavities in protoplasm, used in excretion

In the study of plants we have seen how various forms start in a one-celled stage, the egg, and develop into very complicated forms with separate tissues of various kinds of cells. We have seen also that there are plants so simple that they never have more than one cell, in which is performed all the functions necessary to the plant. With animals the same conditions are found; there are the very complex types such as birds, insects, and man where each function has many sorts of cells (tissues) concerned in its performance—while at the other extreme, there are simple one-celled animals, all of whose life functions are performed in their single, microscopic cells. These simplest forms are called the protozoa (first animals) and though vastly numerous and widely distributed, they are not familiar because of their small size. Small as they are they are very important in nature, forming food for higher animals, acting as scavengers, causing disease in a few cases, and even forming layers of the earth by the deposit of their countless shells, as in the case of the chalk-making forms.

Amœba. One of the simplest of these simple animals is the amœba which lives in the slime at the bottom of most streams and ponds. Though barely visible to the naked eye, under the microscope it is seen to consist of an irregular mass of jelly-like protoplasm without even a cell wall, hence its body (the one cell) constantly changes shape, with a sort of flowing mo-

tion. A nucleus may be seen as well as tiny particles of food which are scattered through the protoplasm, and also a bubble-like cavity (vacuole) which expands slowly and then contracts suddenly, forcing out its contents. Simple as is its structure, one learns to look with respect and interest upon an animal



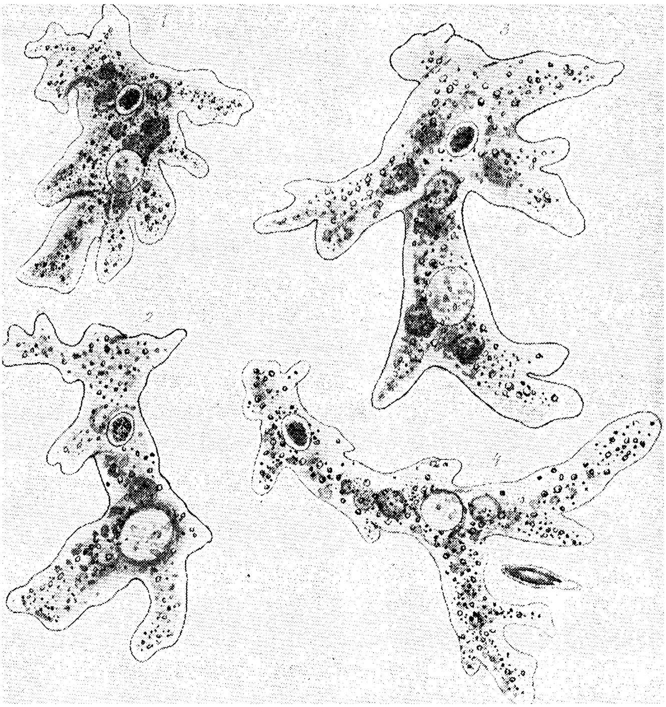
From Calkins.

FIG. 5C. Amœba in active moving condition. c. v., contractile vacuole; f. v., food particle; w. v., water vacuoles; p, remains of former lobe; n, nucleus. Arrows indicate direction of flowing lobes by which it moves.

which with so little material, can yet perform all the functions necessary to any organism, however complex.

The amœba obtains food by extending lobes of its protoplasm and actually flowing around each particle. Digestion and assimilation go on directly in contact with the food, and undigested particles are merely left behind when it flows away from them or they pass out through any part of the cell. Oxygen is taken by contact from the water in which it is dissolved and combines directly with the food and protoplasm producing

energy, just as in all living things. The contractile vacuole acts as an excretory organ, getting rid of waste. Locomotion is secured by the flowing of the protoplasm, projections being pushed out on one side and withdrawn on the other. Some



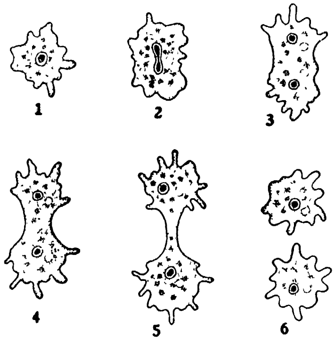
From Kellogg.

FIG. 57. Amœba, showing various forms assumed by the same individual in locomotion and food getting. In stage 4 it is about to surround a food particle.

form of sensation must be present because it responds to light, food, moisture, or sudden jars.

Reproduction occurs as soon as growth reaches a certain size. The nucleus first divides into two similar portions, then the rest of the protoplasm gradually separates into two masses, each with a nucleus and capable of independent life and growth. This simple reproduction by mere division is called *fission.*

There are nearly a thousand close relatives of the amœba, some of which attach a protective covering of tiny sand grains to their body; others secrete a layer of flint or lime. These shelled protozoans are so abundant in the tropical seas that they tinge the water white and their shells, falling to the bottom, make deposits of limestone, such as the chalk cliffs of England.



After Schultz.

FIG. 58. Stages in the reproduction of amœba by the process of cell division or fission.

Paramecium. Another common protozoan is the paramecium which is also abundant in stagnant water. We cultivate it in the laboratory by putting some dry hay or leaves in water and leaving them in a warm place for a few days. The liquid will soon be swarming with various kinds of protozoa, of which many are paramecia.

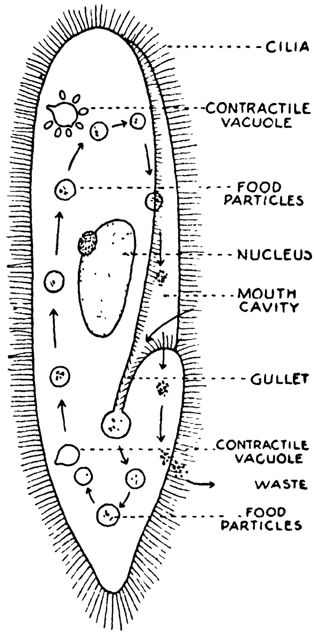
Structure. The paramecium has a cell wall which gives it a definite oval shape. There is also a funnel-shaped cavity on one side which acts as a mouth. The cell is covered with tiny hair-like *cilia* by which the paramecium swims rapidly and also paddles food particles toward the mouth cavity. The cell is composed of protoplasm, nucleus, and contractile vacuoles. The latter are two in number and situated in definite places at the two ends of the cell.

Specialization. Now you can understand that while the paramecium and amœba perform similar functions, still, the paramecium is much more fully adapted for them, insomuch as it has a fixed shape; cilia for locomotion and food-getting; a definite mouth and gullet, and definite regions for excretion. This increase in adaptation of structure to function is called specialization, or division of labor, and is the mark of higher development in any plant or animal.

Reproduction. In paramecium this function may involve two processes, fission and conjugation. Fission takes place,

preceded, as usual, by the division of the nucleus, and two new individuals are produced, much as in amœba. Fission can go on indefinitely under favorable conditions, but usually after a limited number of divisions, the process of *conjugation* occurs.

In conjugation, two paramecia unite by joining the region near the "mouth" cavity, and their cell wall becomes thin at the point of union. Complicated divisions take place in the nucleus of each and finally a stage is reached where there are two parts to each nucleus, one of which is stationary and the other not. The two movable nuclei now exchange places by passing through the protoplasm of the cells and finally uniting with the stationary nucleus of the opposite individual. After this exchange and union of nuclei the paramecia separate again. There has been no gain in numbers but the vitality of the protoplasm has been increased so that reproduction by fission can go on again.



Adapted from Parker.

FIG 59. Paramecium. The actual size is about 1/125 inch in length. Arrows show route of food particles.

This conjugation does not make more individuals as true reproduction does, but it enables both participants to reproduce by fission and is similar to fertilization in plants, since it is the union of two different cells from two individuals.

Parasitic Protozoans. Some protozoans are parasitic, attacking other animals and producing serious diseases, much as do the bacteria. They are often classified with the latter as "disease germs" or "microbes." If we realize that these terms include both one-celled parasitic plants (bacteria) and one-celled parasitic animals (protozoa) then their use is correct.

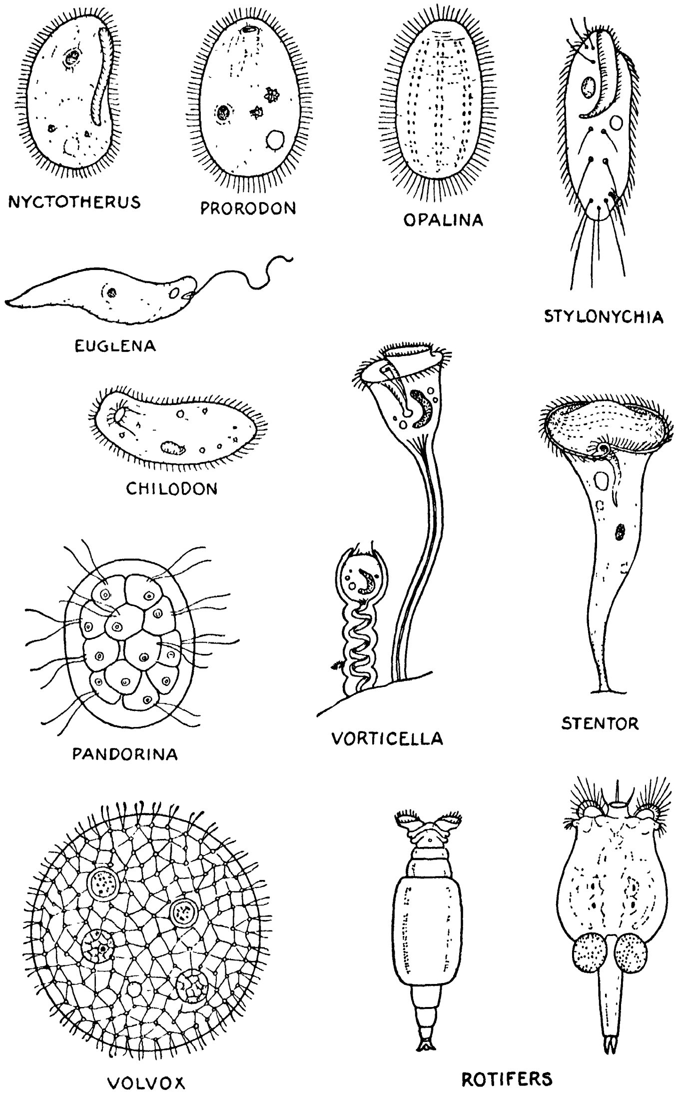


FIG. 60. Various kinds of protozoans, rotifers and other organisms often found in aquarium cultures. (Greatly enlarged).

Some diseases caused by protozoan parasites are in the following list. The way in which they are transmitted will be more fully discussed under insects (Chapter XXV).

malaria	sleeping sickness	smallpox (?)
yellow fever (?)	syphilis	trachoma (?)
amœbic dysentery	Texas cattle fever	scarlet fever (?)

COMPARISON OF AMŒBA AND PARAMECIUM

	Amœba	Paramecium
Form	Variable	Constant
Cell wall	None usually	Present
Locomotion	Flowing lobes	Cilia
Speed	Slow	Rapid
Food taken in	At any point	At definite region
Reproduction	Fission	Fission
Food-getting	By flowing lobes	By cilia
Oxidation	Contact with dissolved air	Same
Excretion	Vacuole, variable	Two vacuoles, definite
Locomotion	Lobes, variable	Cilia, definite
Sensation	Responds to heat, light, contact, moisture, etc.	Same

COMPARISON OF FISSION AND CONJUGATION

Fission (increases numbers).
1. Nucleus divides.
2. Cell divides.
3. Growth to adult size

Conjugation (increases vitality).
1. Union of two individuals.
2. Complicated nuclear division.
3. Cross transfer of part of nucleus.
4. Union of portions of nuclei.
5. Separation of individuals.

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Streams, Furneaux, pp. 99–113; *Protozoa*, Calkins, entire; [1] *Proto-Zoölogy* Calkins, entire; [1] *General Biology*, Sedgwick and Wilson, pp. 192–201; *Practical Zoölogy*, Hegner, pp. 218–233; *Biology of Man and Other Organisms*, Linville, pp. 6–13.

See also references on "Insects and Disease."

[1] Look through, note pictures especially.

SUMMARY OF CHAPTER XVIII

PROTOZOA

1. **All living things** *start* in one-celled stages.
   - a. Sperm and egg cells in higher forms.
   - b. Bacteria (one-celled plants).
   - c. Protozoa (one-celled animals).

2. **Protozoa.**
   - a. Characteristics.
     - (1) Minute size.
     - (2) Numerous.
     - (3) Widely distributed.
     - (4) One-celled simple structure.
   - b. Economic importance.
     - (1) Food.
     - (2) Scavengers.
     - (3) Soil and rock formation.
     - (4) Producing certain diseases.

3. **Examples of protozoa.**
   - a. Amœba (a very simple protozoan).
     - (1) Where found.
     - (2) Appearance.
     - (3) Structure.
       - (a) Protoplasm.
       - (b) Nucleus.
       - (c) Lobes.
       - (d) Vacuoles.
       - (e) Food grains.
   - b. Paramecium (a more specialized protozoan).
     - (1) Where found.
     - (2) Appearance.
     - (3) Structure.
       - (a) Protoplasm.
       - (b) Nucleus.
       - (c) Cell wall.
       - (d) Cilia.
       - (e) "Mouth."
       - (f) Vacuoles.
       - (g) Food grains.
     - (4) Points of advance over amœba.
       - (a) Fixed shape (cell wall).
       - (b) Cilia for locomotion and food-getting.
       - (c) Definite mouth region.
       - (d) Two definite places for excretion.
       - (e) Reproduction both by fission and conjugation.

CHAPTER XIX

METAZOA

Vocabulary

Metazoa, "animals further along," that is, in development and specialization, many-celled animals.
Specialization, development of separate organs for different functions, division of labor.
Respective, separate or individual.
Stimuli, any outside forces that affect plant or animal, such as light, heat, contact, sound, etc.

All one-celled animals are called protozoa (first animals); all those consisting of more than one cell are called metazoa (animals further along), meaning that they are more complex in structure and more specialized in function than a single-celled animal can be.

Development. No matter how complicated a plant or animal may eventually become, it started in a one-celled stage, the fertilized egg. This in turn was the product of the union of the single sperm cell with the single egg cell. To trace the development from this one-celled stage to the highly complicated forms is too difficult at present, and forms the basis for the whole science of embryology. However, some of the steps in the process can be briefly mentioned.

A one-celled animal (protozoan) takes in food and oxygen, and excretes waste only by means of its exposed surface. If the diameter of a solid be doubled, its bulk increases faster than its surface. Hence if a protozoan increased much in size, it would reach a point where the surface was too small to provide for the bulk, and it would die. Before this point is reached, division takes place and growth begins again, up to limit of size set by the ratio between surface and bulk. This is why protozoa are so small and why they divide so frequently. The size which a cell may reach is therefore limited by the extent of its surface.

The paramecium is much more highly developed than the amœba but a limit to its specialization and growth is soon found and a stage is reached where further increase in size is no longer possible. If advance in adaptation is to be continued, larger and more complicated forms must develop.

Suppose that when a protozoan divides, the cells did not separate but remained attached, grew, and divided again and

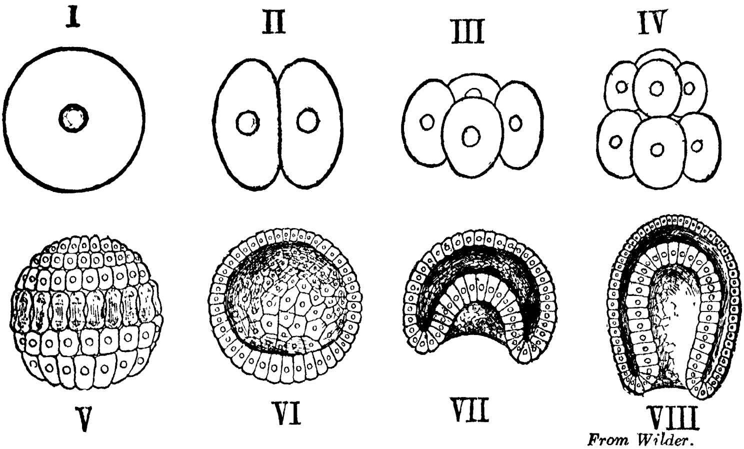


FIG. 61. Early stages of metazoan development. I. Single cell stage, the egg. II. Cell divided but parts do not separate. III and IV. Development of a solid mass of cells. V and VI. Surface and section views of the hollow sphere stage (blastula). VII and VIII. Section views of the infolded wall stage forming two cell layers, the ectoderm (outer), and endoderm (inner). In more advanced forms a third layer (mesoderm) develops between them. See summary at end of chapter for further development of these layers.

again. There would soon be produced a *mass of cells* much larger than any single one, and with abundant surface exposed for food-getting and breathing. In such an animal the outer cells could best attend to locomotion, sensation, and food-getting, while the inner cells could carry on digestion and reproduction. Pandorina and other colonial protozoans represent this stage.

If a solid mass of cells continued to enlarge, the innermost ones would be so far from contact with food and air that a limit in size of the mass would be reached, just as with the

single cell. To meet this condition, the next higher forms consist of *hollow spheres* of cells, thus giving an inner and outer surface, and permitting much larger and more complicated forms. Volvox is a representative of this condition. It consists of thousands of cells, is large enough to be visible to the eye, and has very highly developed reproductive and locomotor cells.

A hollow sphere cannot increase indefinitely in size as the single cell layer would not be strong enough, so in the next higher forms an infolding of the wall takes place, much as a hollow rubber ball can be squeezed into a *cup-shaped form.* Its walls will now be double with a space between them, in which a third cell layer later develops. From these three layers are produced all the tissues of higher forms.

It is important to remember that every plant and animal began life as a single cell, the fertilized egg. This by repeated divisions passed through the stages just described, developed from a mass of unspecialized cells into higher forms with tissues and organs. Finally it reaches its destined stopping place whether in the simple volvox or the complicated insect, bird, or man.

Specialization. Robinson Crusoe on his desert island had to perform all the processes needed to supply his wants. He had to catch and prepare his food, make his clothes and shoes, build his house and defend himself against enemies. Even though he became somewhat skillful at all these duties he could never hope to excel in any. He was, in fact, in the position of the protozoan where all the life functions are performed by one cell. Even though that cell be highly developed as in paramecium or vorticella, still its limit of advance is soon reached.

Now, if there had been ten men shipwrecked with Crusoe, it would have been possible for one to get food, another to prepare it, others to build houses and so on. The increase in numbers permitted division of labor. This is precisely the case with such forms as volvox and all higher types; the increase in the number of their cells makes possible a separation of life functions, which is actually division of labor among cells.

To return to the desert island again, if one man continued making shoes or another did all the building, each would soon acquire skill and perform his duty better; he would have be-

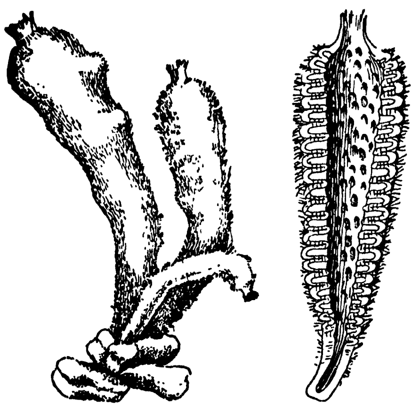
By increase in numbers
Division of Labor is made possible,
by which

Workmen	**Cells**
gain	**gain**
Fitness	**Adaptation**
for	**for**
Business	**Function**
called	**called**

SPECIALIZATION

FIG. 62. Chart showing development of specialization.

come a specialist in his line. Cells also are able to perform their functions better and better by constant use. Specialization is the term applied to this condition in cells as well as in men.



From Jordan and Kellogg.

FIG. 63. A simple form of sponge, half natural size. The section at right shows the body cavity and openings into it at top and through the walls.

Finally, both cells and men would acquire special fitness for their tasks. This special fitness is called adaptation and is the permanent result of specialization. The more perfectly a plant or animal is adapted to its environment, the better is its chance to survive; hence this matter of development, division of labor, specialization and adaptation is of the utmost importance.

Interdependence. There is, however, another phase of this matter of specialization which cannot be overlooked. The man

who devotes himself solely to the making of shoes, loses the ability to do many other necessary things. Cells and tissues which become adapted for special functions are all the more dependent upon other specialized cells for equally important services. So it comes to pass that the more highly specialized a plant or animal becomes the more each part depends upon all the others, and the more difficult it is to replace or to do without a damaged tissue or organ.

Forms of Metazoans. The sponges have their division of labor confined to specialization of separate cells for various functions. The next higher group (cœlenterates) which includes the hydra, coral polyps, sea anemone, and jellyfish, have cells performing similar functions grouped together in true tissues.

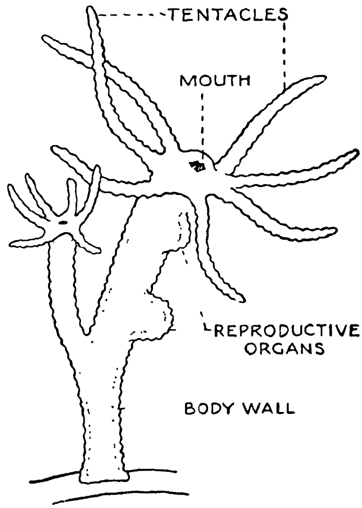


Fig. 64. The hydra, a simple cœlenterate. Hydra represents a degree of specialization somewhat in advance of the sponges.

The next group (true worms), such as the earthworm, carry this division of labor still further, having special digestive, circulatory, and excretory organs, of complicated structure, and a true nervous system with the beginning of a brain.

Still more complicated in structure and specialized in function are the molluscs which include clams, oysters, snails, squids, and devil fish. These have very complicated gills for breathing, heart and circulatory system much more developed, muscular and nervous systems becoming more efficient. In some there are found eyes and other sense organs.

The arthropods, which include the lobster and crab, all insects, and spiders, constitute an enormous and highly specialized group whose adaptations we shall study in detail. Then at the top of the list come the vertebrates, including all back-

boned animals, fish, frog, snake, bird, cat, and man whose place at the head of the class is due, as always, to the specialization and development of the organ with the highest function, namely, the brain, with its ability to think and reason.

All this increase in adaptation brings the animal in closer touch with its surroundings or environment. The amœba vaguely turns toward food and moisture, contracts if disturbed or perhaps turns away from strong light. As development progresses, response is made to other outside forces (stimuli) and we have organs for touch, taste, smell, hearing, and sight, all of which enable the animal to adapt its life to its environment and by that means become successful in the struggle for existence which goes on with its neighbors.

COLLATERAL READING

General Zoölogy, Linville and Kelly, pp. 292–304; *Animal Life*, Jordan and Kellogg, pp. 24–49; *Animal Studies*, Jordan, Kellogg and Heath, pp. 33–42; *Animal Life*, Thompson, pp. 143–152; *Comparative Zoölogy*, Kingsley, pp. 318–320; *Elementary Zoölogy*, Kellogg, pp. 57–63.

SUMMARY OF CHAPTER XIX

METAZOA

1. Development.

- a. Plant and animal *begin* as single cells (sperm, ovule).
- b Stages of progress.
  - (1) One cell.
  - (2) Two cells to many in mass (pandorina, other colonial protozoans).
  - (3) Hollow mass of cells (volvox, other colonial protozoans).
  - (4) Infolded, hollow form (sponges).
  - (5) All higher forms.
    - (a) Tissues develop from layers of previous form.

2. Specialization.

- a. Beginning as single cell.
- b. Increase in number of cells.
- c. Separation of functions (division of labor).
- d. Better performance of functions (specialization).
- e. Development of fitness for functions (adaptation).

3. Interdependence.

- a. Advance in development means advance in adaptation.
- b. Advance in adaptation means closer contact with surroundings.
- c. Both of which means success in the struggle for existence.

4. Comparison of Protozoa and Metazoa.

Protozoa	Metazoa
One-celled	Many celled
No specialization in simplest except the nucleus	Specialized tissues and organs
Some have a cell wall, cilia, "mouth" but no regular systems of organs	Digestive, respiratory, nervous systems, etc.
Reproduce by fission	Reproduce by eggs and sperms
Excretion by vacuoles	Excretion by kidneys, or analogous organs, skin, and lungs
Minute size	Much larger size
No "body wall" either in embryo or adult	Three layers in embryonic body wall in higher forms which develop as follows: 1. Ectoderm, forms outer skin and its appendages:—Nervous system and sense organs 2. Mesoderm, forms inner skin, fat, bone, muscle, connective tissue, serous membranes 3. Endoderm, forms mucous membranes and all organs that it lines, gills, lungs, glands

5. Development of Metazoa.

Groups of Metazoans	Degree of Specialization	Representative
1. Sponges	*Cells* adapted for food getting, digestion, reproduction, etc.	Bath sponge
2. Cœlenterates	*Tissues* for the above processes and for locomotion	Hydra Jelly fish
3. Worms	*Organs* well developed, nerves, blood vessels, muscles, etc.	Earthworm
4. Molluscs	Sense organs, gills, heart, etc., more complicated	Snail Clam
5. Arthropods	Great specialization, external skeleton, all senses, very active, nervous system and instinct	Insects Crayfish Spiders
6. Vertebrates	Great internal specialization, high special senses, brain, instinct, and reason, varied locomotion, internal skeleton	Fish Frogs Reptiles Birds Man

CHAPTER XX

WORMS

Vocabulary

Anterior, the end toward the head, usually the end that precedes in locomotion.
Posterior, the end farthest from the head.
Analogous, having similar function.
Homologous, having similar structure or origin.
Setæ, hair-like projections by which some worms move.

The worms may be taken as a class of animals showing a moderate degree of specialization. They include the common earthworm, bloodsuckers, tapeworms, horsehair worms, etc.

Many animals are called worms, which are not true worms at all, but are merely a larval stage in the development of some insect. Such are "apple worms" which are the larvæ of a moth, "wire worms" which are the larvæ of a beetle, "cabbage worms" which develop into the common white butterfly, and so on.

Almost any crawling animal may have the name "Worm" applied to it, though usually incorrectly. On the other hand, "vinegar eels" and "horsehair snakes" are true worms, as are also "bloodsuckers" or leeches.

The Earthworm

The earthworm is the commonest example and will be used as a type of the group. If you have been so fortunate as to live in the country, you have probably "dug worms" to use as bait for fishing or you may have caught them at night on the lawn. In this latter case you had reason to observe a curious habit of the earthworm.

As you search in the grass with your light, you must step carefully as the worms can feel a jar of the ground and will go back into their burrows if disturbed. If you are cautious, you

will find them, with the tail still in their burrow, feeding on leaves or pulling them under ground. You have to be rather quick to pick one up, and unless you are careful, you may pull it in two, for the worm keeps its tail segments in the mouth of its burrow and expands them when disturbed, thus holding tightly to the ground and rapidly withdrawing its whole body if opportunity affords.

External Features. Examination of a living specimen shows the familiar, slender "worm shaped" body covered with a thin skin and divided into rings or segments.

The larger end, near which is a light colored girdle, is the head (anterior) end. The vent, or opening of the intestine, marks the opposite (posterior) extremity. Projecting from each segment are four pairs of bristles (setæ) which are operated by separate muscles and are used in locomotion. The girdle secretes the case in which the eggs are deposited and near it are the tiny openings of the egg and sperm ducts, since the organs of both sexes are found in the same animal. On opening the body, the wall is found to consist of cuticle, epidermis, and two thick layers of muscle, one running lengthwise, and the other around the body.

Digestive System. Inside the body wall, the large digestive system can easily be recognized, there being a muscular pharynx, a crop, gizzard, and long, straight intestine, terminating at the vent.

Circulatory System. Not so conspicuous is the circulatory system which consists of two large blood vessels, one above, the other below the digestive tract, connected by branches in each segment. Some of these branches pulsate, acting as a heart, to drive the blood through the system. It must be remembered that the function of any circulatory system is transportation. It carries food from the digestive organs to the tissues, oxygen from the breathing organs to the tissues, and waste products from tissues to the organs of excretion. In all animals less specialized than the worm, the structure was simple and in some cases these processes were carried on directly by osmosis. In the worm, division of labor is more complete, the

various tissues more complicated and so, for the first time, a transportation system is developed.

Excretory and Nervous Systems. Besides the circulatory organs, there are rather complicated sets of tubes in each segment, which excrete waste matter. There are two sets of reproductive glands between the pharynx and gizzard. On the lower (ventral) side of the body is a row of light-colored threads (the nervous system), enlarged in each segment, and ending in a tiny knob near the mouth, which corresponds somewhat to the brain. When such an animal is compared with the paramecium, it is evident that its functions have much more specialized machinery for their performance.

Locomotion. The worm is adapted for locomotion by the body muscles and setæ. The muscles extend the anterior part of the body, the setæ are slanted backward and grip the soil, and the posterior part of the body is pulled forward with a sort of wave-like motion. By this means the worm travels on the surface or burrows in the ground. Burrowing is assisted by the fact that the earthworm practically eats its way, taking the soil into its digestive tract, absorbing what organic matter it can use as food, and bringing the unused earth to the surface as "worm castings." These are often seen on lawns, tennis courts, and golf greens.

Analogous Organs. Organs in different animals which perform similar functions are called analogous organs. The setæ and muscles of the worm are analogous to the cilia of the paramecium, or the flowing lobes of the amœba in respect to their use in locomotion. (What analogous organs in fish, bird, and man?)

Food. The food of the earthworm consists of leaves of cabbage, celery, and other plants, as well as some kinds of meat, together with organic matter found in the soil. This is gathered at night, taken into the burrows and eaten. The waste is brought to the surface with the earth as castings.

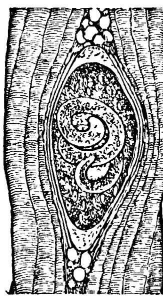
Economic Value. This method of feeding loosens and enriches the soil, performing about the same work as does the farmers' plow, though to a greater extent, for the worms are

found in all parts of the world, in such numbers that they pass through their bodies an average of ten tons of soil per acre, every year, and thus do an incalculable service to the farmer. The humble earthworm, whose function may have seemed to be to furnish bait for fishing, now is seen to be a very useful member of society. It has, however, some very bad relatives, which do a great deal of harm and therefore require special mention.

Parasitic Worms

In this group are included the tapeworm, trichina, hookworm, and many others. As is often the case, they are harmful because parasitic. A parasite, as has been said, takes the nourishment of another creature instead of getting its own.

Tapeworm. The tapeworm lives first within the body of pigs or cattle, the egg being taken in with their food. It develops in the intestine, bores its way into the muscles and goes into a resting stage. If the flesh of such animals be eaten when not thoroughly cooked, the development continues in the intestine of man. The worm attaches itself by its head, lives on the digested food with which it is surrounded, robbing its host of needed nourishment. It produces segment after segment till a length of thirty feet may be attained. These segments are practically sacs of eggs which break off from time to time, allowing the eggs to escape, dry, and scatter, where hogs or other animals may eat them and start the circle over.



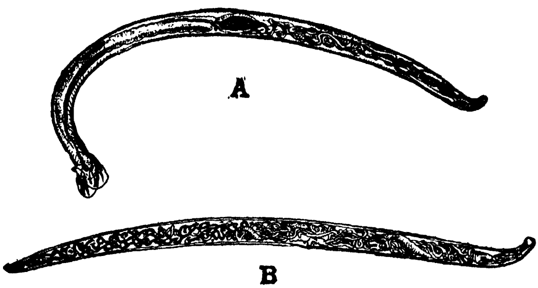
From Hertwig.

Fig. 65. Trichina enclosed in cyst in muscle of pig; very much magnified.

Trichina. Round worms are another class many of which are parasites. The "vinegar eel" and the intestinal pin worms are comparatively harmless forms. The pork worm (trichina) of this same class may cause serious illness or death. These worms pass their first stage in the pig, dog, cat, rat, or horse, where they bore into the muscles, surround themselves with a coating (cyst), and remain alive but inactive. If such flesh be eaten when improperly cooked, the cyst is dissolved, the worms

develop, mate, and the young embryos bore through the tissues again. This produces the painful and often fatal disease known as trichinosis. The tapeworm is large; usually only one is present and it does its chief harm to man by absorbing food needed to nourish the body. The trichina, on the other hand, is microscopic in size, vastly numerous, and produces acute disease by penetration of the tissues. Careful inspection and thorough cooking of meats are lessons to be learned from the above life histories.

Hookworm. The hookworm is another parasite, found in the southern states, which attacks man most often by way of the feet. Thence by way of the veins, lungs, and throat it penetrates to the intestine, where it absorbs food and causes loss of blood. It is also introduced into the body through food that has been in contact with infected soil. It lowers its victim's strength and produces a characteristic laziness. Almost all animals, from clams and insects to cattle and man, are subject to the attacks of parasitic worms. The hookworm alone costs this country about twenty million dollars per year, in loss of labor due to its effect on health.



From Wilder.

FIG. 66. Hookworm. *a*, male; *b*, female. (Greatly enlarged.)

The "horsehair snake" which you frequently find in ponds and streams has nothing to do with a horsehair, nor is it a snake. It is one of the round worms (related to the "vinegar eel" which is also not an eel) and is parasitic upon beetles, grasshoppers, and other insects, thus doing considerable good.

Comparison of Life Histories of Three Dangerous Worms

Tapeworm	Trichina, Pork worm	Hookworm
Adult segments pass off in intestinal waste These are really egg masses	Adults produce living young,	Eggs pass off in waste
Eggs eaten by hogs or cattle	Hog may get them from rats or pork in its food	Eggs hatch into larvæ in moist soil
Hooked larvæ bore into muscle making "measly" pork or beef	Young bore into flesh and form cysts; cause disease in hog	Bore through skin of feet May get in via food
Flesh not well cooked eaten by man	Flesh not well cooked eaten by man	Penetrate into blood vessels, thence to trachea, and are swallowed
Larvæ develop into adult in intestine and attach to wall by hooked head Absorb digested food and produce eggs	Cyst dissolved and after two days larvæ bore into the muscle, causing disease If patient survives, they form cysts and are inactive	Attach to upper intestinal wall and suck blood Produce more eggs
Usually one large worm in the intestine	Numerous small worms in the muscles	Numerous small worms in the intestine
Robs body of food Interferes with digestion Lowers vitality	Causes acute painful and often fatal disease	Produces anæmia and lowers vitality
Remedy, meat inspection and thorough cooking	Remedy, meat inspection and thorough cooking	Proper disposal of body wastes, shoes Cleanliness Easily cured by simple treatment

The Parasitic Habit. As is always the case when we try to get along without work, we damage ourselves in the end. The parasite, whether a worm or a human being, pays certain penalties for its habit of life.

In either case the parasite loses ability to provide for himself, what he takes from another. With the worms this has resulted in actual loss of organs of locomotion and food-getting. Some, like the tapeworm, have degenerated into mere absorbing and reproducing devices.

This means absolute dependence on the host organism and as the chance of finding a suitable host is not usually great, there must be a vast production of eggs, if even a few are to survive. It is a curious fact that parasites have developed in many groups of plants and animals, and have found this method of life successful enough to let them survive, but it has always been at the expense of individual independence.

COLLATERAL READING

Vegetable Mould and Earthworms, Darwin, entire; *Life and Her Children*, Buckley, pp. 135–152; *Economic Zoölogy*, Osborne, pp. 67–120; *Economic Zoölogy*, Kellogg and Doane, pp. 98–105; *Elementary Text*, Linville and Kelly, pp. 195–235; *Practical Zoölogy*, Davidson, pp. 150–161; *Applied Biology*, Bigelow, pp. 340–354; *Animal Studies*, Jordan, Kellogg and Heath, pp. 59–88; *Life in Ponds and Streams*, Furneaux, pp. 114–126.

Practical Zoölogy, Hegner, pp. 168–191; *Biology of Man and Other Organisms*, Linville, pp. 27–35.

See also articles under "Worms," "Tapeworm," "Trichina," "Leech" in encyclopedias.

SUMMARY OF CHAPTER XX

WORMS

1. Kinds.

a. Earthworm.
b. Tapeworm.
c. Hairworm.
d. Vinegar "eel."
e. Leech.
f. Etc.
g. Caterpillars, etc., are not worms.

2 External structure.

a. Segments.
b. Girdle.

(1) Function.
c. Mouth (pre-oral lobe).
d. Setæ.
(1) Location.
(2) Functions.

3. Internal structure.

a. Body wall.
b. Digestive system.
c. Circulatory system.
d. Excretory system.
e. Nervous system.

4. Adaptations.

a. For locomotion.
(1) Body muscles (two layers with different motions).
(2) Setæ with individual muscles.
b. For burrowing.
(1) Setæ and muscles.
(2) Habit of swallowing earth through which it goes.
(3) Evidence shown by "castings."

5. Economic value.

a. Nature of food used.
b. Loosening and turning of soil.
c. Enriching soil with organic matter.

6. Parasitic worms.

a. Tapeworm.
(1) Life history and economic importance.
b. Trichina.
(1) Life history and economic importance.
c. Hookworm.
(1) Life history and economic importance.

CHAPTER XXI

ARTHROPODS

Vocabulary

Segmented, made up of joints or sections.
Dorsal, the region of the back, usually, but not always, uppermost in animals.
Ventral, the side opposite the dorsal, the region of the belly, usually underneath.
Genus, next to the smallest general division in classification; plural is genera.
Species, the smallest general division in classification; plural is also species (specie means money).

The group of animals next to be studied is called the arthropods (jointed foot) because all their leg-like appendages are divided in joints or segments.

Characteristics. They are the largest group of living things in the world, outnumbering all the other species of the animal kingdom. These numerous forms all agree in the following points:

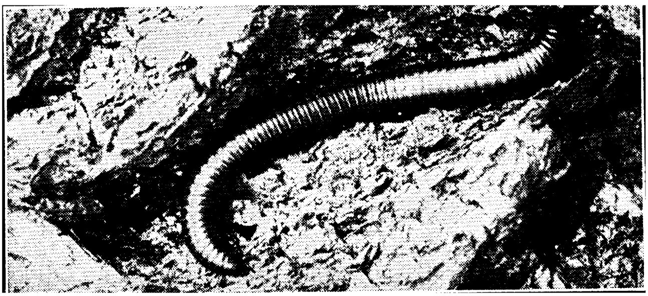
1. They have jointed appendages.
2. They have an external skeleton.
3. The body is segmented and consists of three regions,
   (a) head specialized for food-getting and sensation.
   (b) thorax for locomotion.
   (c) abdomen not highly specialized.
4. Heart is in the back (dorsal) region.
5. Nervous system is beneath (ventral).

Classes. The arthropods are divided into four *classes*, the fourth being rather indefinite, and including the worm-like forms such as the centipedes and "thousand legs."

1. Crustacea, which include crayfish, lobster, crab, shrimp, and many others.

2. Arachnida, the spiders.
3. Insecta, the insects.
4. Myriapods, worm-like forms.

The members of each of these classes have all the characteristics of the arthropods, but there are additional points of resemblance within each class. For instance, most crustacea have the head and thorax united into a cephalo-thorax (head-thorax) which is covered by a part of the external skeleton



From L. W. Brownell.

FIG. 67. A millipede, representative of the class of myriapods.

called the carapace. Usually they have five pairs of legs and breathe by gills attached to them.

The arachnida (spiders) have four pairs of legs and breathe either by air sacs or by tracheæ. The insects' head and thorax are separate; they have three pairs of legs and usually wings as well, and breathe by means of tracheæ. (For further comparison see tabulation.)

Classification. Each of these three classes is further divided into groups called *orders*, the orders into *families*, and the families into still smaller groups called *genera* (singular: genus) and genera into *species* (singular: species also).

As we come down in the classification, the groups have more and more points of resemblance, but of course include fewer individuals. Take, for instance, the common grasshopper; it belongs to the

Branch of the animal kingdom called arthropods
Class, insecta
Order, orthoptera
Family, acrididæ
Genus, melanoplus
Species, femur-rubrum.

We do not have to learn these apparently difficult names. What we ought to try to understand is the *method* of classification, because it is used in all animal and plant groups and is so well illustrated by the arthropods. In the case of the grasshopper, the *species* group includes just that one kind of grasshopper and no others so they are alike in all points; the *genus* includes several species with a good many points of resemblance. The *family* includes the members of several genera which resemble each other but less closely than the members of the genus. The *order*, orthoptera, includes several families with members as different as the cockroach, locust, katydid, grasshopper, and crickets, while the *class* insecta includes all the different orders of insects, such as bees, moths, flies, and beetles which of course include many individuals but resemble each other in still fewer points. As stated before, the Insecta is one of the four classes into which the arthropod branch is divided and has the characteristics of that enormous group, in common with the arachnida, crustacea, and myriapods.

Value of Scientific Classification. This may seem very complicated but is really very necessary, for if there were no way of grouping the different forms, they could never be studied or understood, much less named and identified. Not only this, but resemblance in points of structure shows actual relationship, those forms most alike being nearest related and those with less points in common, more distantly connected. Classification is not only a convenient arrangement to save labor in the study of living things, but shows their relationship and descent, as well.

Let us classify the grasshopper fully according to this outline, and see how much is included in merely its proper scientific classification.

Kingdom: Animal
Branch: Arthropoda (jointed-foot animals)
Class: Insecta (body "cut into" three regions)
Order: Orthoptera (straight-winged)
Family: Acrididæ (locust family)
Genus: Melanoplus (black armored)
Species: femur-rubrum (red-legged)

From just the translation of the names used, one can obtain a fair description of the animal concerned, and if the characteristics of each successive group are known, a complete description is obtained.

If a person in Africa were addressing a letter to this country, and gave a full and exact address, it would cover as many items, as the following comparison shows.

Grasshopper	Letter
Kingdom: Animal	Nation: United States of America
Branch: Arthropoda	State: Illinois
Class: Insecta	City: Chicago
Order: Orthoperta	Street: Madison
Family: Acrididæ	Number: 3561
Genus: Melanoplus	Surname: Smith
Species: femur-rubrum	First name: John J.

In the case of the letter as many items have been mentioned as with the scientific classification, and for the same purpose, namely, that both shall be absolutely definite and apply to one only. If, in addition, we could so address our letters that the appearance and relationship of the addressee were included, it would correspond to the very remarkable system of classification used in all biologic work.

Scientific Names. When speaking of a plant or animal the genus and species names are usually all that are given, assuming that the relationship to the larger groups will be known. The genus is placed first and begins with a capital letter, the species follows, and begins with a small letter. The genus name is usually a noun and the species name an adjective; the genus name precedes the species name, as is the regular Latin order.

We follow it in our lists of names in all formal records where John J. Smith would appear as Smith, John J. Thus, *Melanoplus femur-rubrum* is the scientific name of the common grasshopper. It is a long name, even for a scientific one, and was chosen on that account, but how much more convenient and accurate than saying "the black-armored grasshopper with red legs."

Another advantage of scientific names is that they are uniform throughout the world. People of all languages use the same name for the same plant or animal in their scientific works, and as a result there is no confusion, nor any need for learning a new set of names. Common local names are always uncertain, for there are often several names for the same plant or animal. With the scientific names there is but one possible, and therefore there can be no chance for mistake.

Scientific names have these advantages:

1. They are absolutely definite.
2. They are used by people of all languages.
3. They are usually descriptive.
4. They are easier to study than separate descriptions.
5. They show relationship and descent.

COLLATERAL READING

Applied Biology, Bigelow, pp. 358–404; *General Zoölogy,* Linville and Kelly, pp. 138–156; *Animal Studies,* Jordan, Kellogg and Heath, pp. 109–129; *Economic Zoölogy,* Kellogg and Doane, pp. 106–125; *Economic Crustacea,* U. S. Fish Commission Report, 1889–1893; *Life and her Children,* Buckley, pp. 153–177; *Zoölogy Text,* Colton, pp. 54–77; *Elementary Zoölogy,* Kellogg, pp. 144–156; *Zoölogy Text,* Shipley and MacBride, pp. 118–135; *Elementary Zoölogy,* Galloway, pp. 232–265.

SUMMARY OF CHAPTER XXI

ARTHROPODS

1. Characteristics.

- a. Jointed appendages.
- b. External skeleton.
- c. Three body-regions.
  - (1) Head (food-getting and sense organs).
  - (2) Thorax (locomotion).
  - (3) Abdomen (reproduction) (less specialized).
- d. Dorsal heart.
- e. Ventral nervous system.

2. Kinds.

Classes	Characteristics	Examples
a. Crustacea	Head-thorax united Carapace, gills Five pair legs	Lobster Crayfish Crab, shrimp
b. Arachnida	No carapace, no gills Four pairs legs Air sacs or tracheæ	Spiders Horseshoe-crab
c. Insecta	Head and thorax separate Three pair legs; wings Breathe by tracheæ	Beetles Grasshoppers Butterflies
d. Myriapods	Worm-like forms	Centipedes

3. Classification.

a. Based on likeness of structure (homology).
  (1) Hence shows relationship and descent.
b. Assists in study and placing of new forms.

4. Divisions of animal kingdom.

Branches.
  Classes.
    Orders
      Families
        Genera.
          Species.

5. Comparison of larger and smaller groups.

a. Larger groups have fewer points in common, more individuals.
b. Smaller groups have more points in common, fewer individuals.
c. Smaller groups have all characteristics of the larger groups of which they are a part, and certain peculiar to their own.

6. Scientific name.

a. Consists of genus and species names.
b. Avoids long descriptions.
c. Is universally used.
d. Makes meaning absolutely definite.
e. Shows relationship of different forms.

CHAPTER XXII

CRUSTACEA, A CLASS OF ARTHROPODS

Vocabulary

Carapace, the external protective covering of the cephalo-thorax in crustacea.
Mandibles, jaw-like organs.
Maxillæ, little jaws, aid in holding food.
Maxillipeds, jaw-feet, aid in catching, holding, and chewing food.
Homology, likeness in structure and origin.
Analogy, likeness in function.

Our study of the worms showed us a group of animals in which tissues and organs had become somewhat specialized, circulatory organs developed, and adaptations formed usually for an inactive or parasitic kind of life. In the crustacea we deal with animals such as crayfish, lobster, and crab, which are adapted for an active, aquatic (water) life, in which division of labor among their various organs has been carried to a higher point.

Characteristics. Although the crustacea include many very different forms, they generally agree in the following points. All have two pairs of antennæ; nearly all breathe by gills; usually the head and thorax are united; the body is nearly always protected by a limy external skeleton.

The Crayfish

External Structure. The crayfish, which we study as a type, has the body covered with a dark-colored, limy, external skeleton (exo-skeleton) divided into two regions, the cephalo-thorax (head thorax) covered by the united carapace, and the abdomen made up of seven separate movable segments. This is the first animal we have studied which has had any skeleton at all and it may seem strange to find it on the outside of the body while ours is inside. However the same functions are

performed in both cases, namely, to protect the organs and act as levers for the muscles.

Protection is most important in the crustacea which really have a suit of mail, such as the knights used to wear. Their joints are made to bend by similar arrangements, only better adapted than man's, and they cover their head and body by a shield (carapace) far lighter and more efficient than ever warrior carried. Not only is their exoskeleton strong, light, and flexible, but it is colored so as to escape notice from enemies (protective coloration). It is also provided with sharp spines and projects downward at the sides, thereby guarding the gills and soft under parts of the body. In addition to its protective function, the skeleton forms a rigid series of levers, by means of which a complicated system of muscles provides for swift motion and locomotion, essential for escape, attack, and food-getting. The development of a skeleton has also enabled its possessor to advance in many ways.

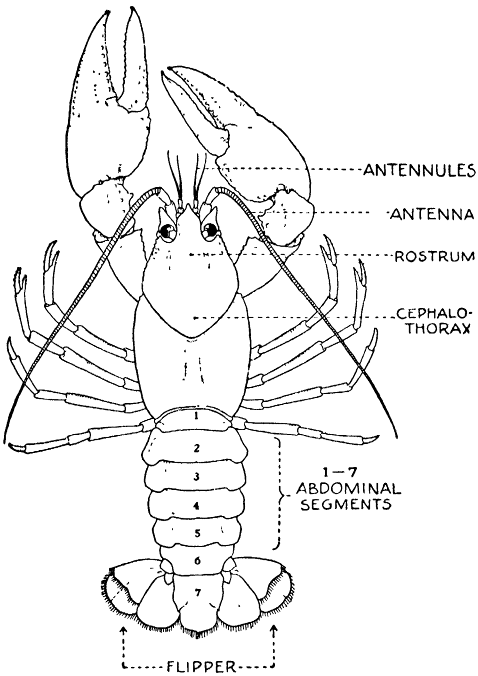


FIG. 68. Crayfish,—a type of the crustacea.

As stated before, the body consists of segments though only the abdominal ones are movable, those of the cephalo-thorax being united for greater strength and protection, while the numerous appendages provide for the needed freedom of mo-

tion. Nineteen of these segments have each a pair of appendages, many of which are adapted for different purposes, though all are developed from the ordinary swimming leg found on the abdomen. The front of the carapace extends forward into a protective beak, the rostrum (why so called?), on either side of which are the eyes, set on movable stalks and each composed of many lenses.

Head Appendages. Beginning at the anterior (head) end, we first come to the small and large feelers (antennæ) at whose base open the "ear sacs" and excretory organs respectively. Then come the true jaws (mandibles) and two pairs of little jaws (maxillæ) which aid in chewing the food. To the posterior maxilla is attached the "gill bailer," a scoop-shaped organ for paddling water over the gills, the flow being toward the anterior. So far, the organs named belong to the head. Notice the various functions performed. Also observe that the jaws work from side to side and not up and down, because they are merely leg-like appendages adapted for chewing and so continue to have a horizontal motion as do the legs.

Thoracic Appendages. The first appendages of the thorax are three pairs of maxillipeds (jaw feet) whose function is holding and chewing food. To these are attached gills for respiration. Next come the large claws, evidently for defence and food-getting, then two pairs of legs with claws at the tip and two more pairs without claws. These four pairs of legs are concerned mainly with walking. To them and to the large claws as well, gills are attached, which extend up under the carapace into the gill chamber.

Abdominal Appendages. The appendages of the abdomen are called swimmerets and are small on the first five segments. They are used in the process of reproduction and by the female for attachment of her eggs. The sixth swimmeret is enormously developed into a wide fin or flipper. The appendage of the seventh segment is lacking and the segment itself reduced to the flat, triangular part called the telson. The sixth and seventh segments together form a powerful organ for backward locomotion, for they can be whipped forward by the strong muscles

of the abdomen and the animal will shoot backward at high speed.

Adaptation. While we do not have to memorize all these appendages, there are two lessons that their study must teach; first how remarkably division of labor may be carried out, and second that we have here the modification of *one* kind of organ for many uses. It will be seen that these various organs are developed from a simple kind of appendage, the swim-

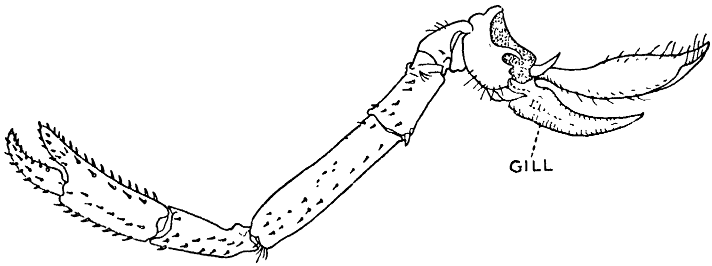
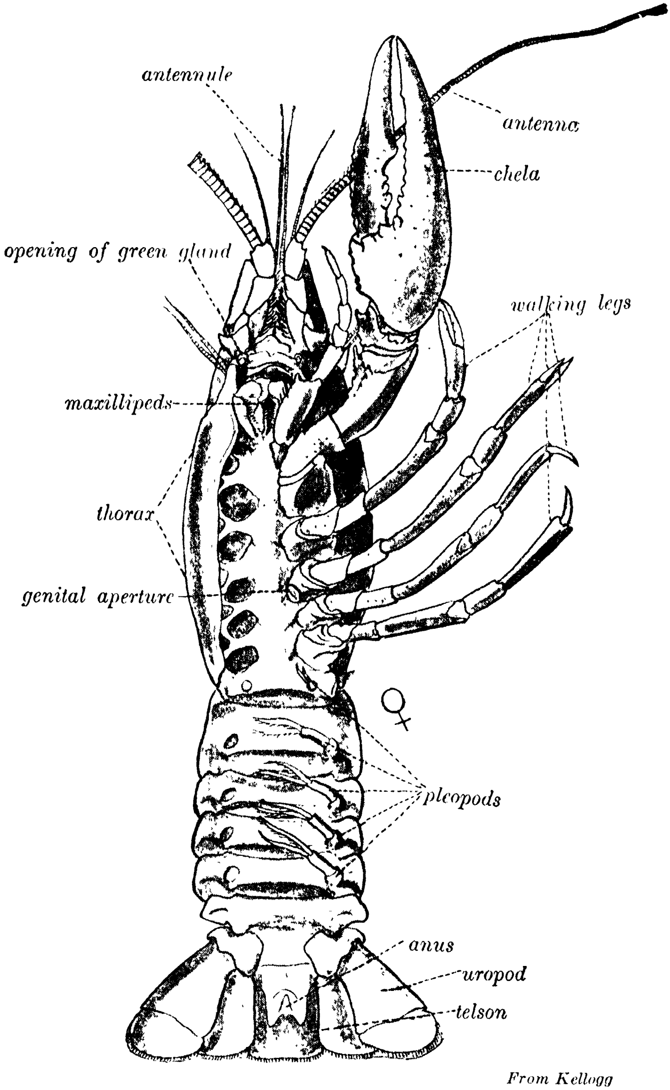


FIG. 69. Second walking leg of lobster with gill attached at the base. Six more or less movable segments and claw are shown.

meret. By the addition and modification of segments, organs have been developed as widely different as the large claws and the antennæ.

Homology. When we find organs (either in the same or different animals) which were developed from the same part, that is, whose origin and structure are similar, we call them *homologous* organs. Thus we may say that the antennæ and claws of the crayfish are homologous to the swimmerets, or that our arm is homologous to the foreleg of a horse, even though the functions are so different. This word is the mate to *analogous* which meant similar in function. We might say that the gills of the crayfish and the lungs of man are analogous, because they both perform the function of respiration but we cannot say they are homologous, since the gills are developed from the legs, while the lungs are outgrowths of the throat.

Internal Structure. Internally, also, there is a considerable degree of specialization. The digestive system and its glands occupy a large part of the cephalo-thorax. There are three



From Kellogg

FIG. 70. Ventral view of crayfish, with the appendages of one side removed.

tooth-like structures in the stomach, which complete the chewing of the food. A well-developed circulatory system and a

muscular heart mark an advance along this line. The excretory and reproductive organs are present and fairly developed. The nervous system, though similar, is much more specialized than in the worms. The senses of touch and smell, located in the antennæ, are probably acute. The eyes are on movable stalks and are compound, each consisting of numerous lenses, but the sight is probably not keen. The "ears" are located at the base of the antennules and probably aid in balancing. Neither hearing nor taste seem to be especially developed.

While these sense organs do not seem very efficient, yet enormous advance can be seen when they are compared with the earthworm with no organs of special sense at all. The worm probably feels only touch and vibration sensations through the body wall, with a possibility of taste and heat or light sensations in the region of the head. Since the degree in which an animal can get in touch with its environment marks the stage of its advancement, the crustacea far excel the worms in development.

Locomotion. This function is provided for by the tail flipper which drives the crayfish swiftly backward, and by the four pairs of walking legs which can travel in either direction and sideways as well. All are operated by powerful muscles, assisted by the exo-skeleton. You can see why the slang expression "to crayfish" means to back out of any agreement when it ceases to look attractive.

Protection. The crustacea's adaptations for protection are the exo-skeleton with its color and spines, the powerful jaws and claws for attack, speed for escape, fairly keen senses, and a nervous system to guide its actions.

Respiration. Respiration in protozoa was accomplished by contact of the cell with dissolved oxygen in the water; in the worm by contact of the body wall with oxygen in the air; osmosis was the method in both cases. In the crustacea we have organs called gills, specially developed for carrying on the exchange of oxygen and carbon dioxide. These gills are thin walled, to allow osmosis, feathery to expose much surface, provided with many blood vessels to receive oxygen and to

liberate carbon dioxide, and also are arranged to insure a constant flow of fresh water over them. This last is brought about in part by the gill bailer, attached to the second maxilla and partly by the gills being attached to the appendages. They therefore move in the water, with every motion of a leg or maxilliped. Finally, as the water passes under the carapace from behind toward the head, this flow is aided every time the animal swims backward. The gills are protected by the carapace, which extends over them and forms a chamber which will hold moisture for some time, thus keeping the animal alive when removed from the water. Notice the importance of the fact that oxygen is soluble in water; if it were not, the aquatic animals could not exist, since it is the oxygen dissolved from the air, and not the oxygen of the water (H_2O) itself which all water animals use.

Food-getting. The food of the crustacea is usually animal, either alive or dead, some even being cannibals, while others act as useful scavengers. A few of the smaller forms are peaceful vegetarians. Their swiftness, claws, mouth parts, color protection, and sense of touch and smell all are adaptations for food-getting and their large number shows how well able they are to cope with their surroundings.

Life History. The eggs, which often number thousands, are laid by the female, fertilized by sperms from the male as they are laid, and attached to the swimmerets where they are carried and protected by the mother for about ten months. The young after hatching, which occurs in summer, cling to the swimmerets for some time. When first hatched they are very small, not entirely like the adult in structure, and they remain at the surface of the water for the first stages. After moulting four or five times, they settle down on the bottom among the rocks, where they live on smaller crustaceans. During these early stages which occupy ten to fifteen days they are nearly defenceless and millions are destroyed by other aquatic animals for food. After reaching the bottom they are somewhat better protected though still destroyed in large numbers. This high mortality is made up for by the

production of large numbers of eggs. During their life at the bottom, moulting occurs at longer intervals until adult size is reached at the age of five years (in case of the lobster) after which they do not moult oftener than once in one or two years.

Moulting. This moulting, or shedding of the exo-skeleton is a direct result of having the hard parts outside. They cannot grow larger except by shedding their armor, and this is a point in which the internal skeleton of the higher animals is a great advantage. With it, growth may be continuous. However, the exo-skeleton provides better protection. When ready to moult, the lime is partly absorbed from the skeleton; the carapace splits along the back, water is withdrawn from the tissues which makes them smaller and the animal literally humps itself out of its former skeleton, leaving behind the lining of its stomach and its teeth. Immediately water is absorbed and growth proceeds very rapidly. The lime is replaced in the new and larger armor and Richard is himself again. Usually the later moults take place in hidden locations and with haste, as the animal is totally helpless and a prey to all sorts of enemies when growing its new suit. It is at this time that "soft shell crabs" are caught. They are merely the ordinary crab in the act of moulting.

Reproduction of Lost Parts. In moulting or in battle with enemies, it often happens that appendages are lost or injured, in which case the limb is voluntarily shed between its second and third segments. A double membrane prevents much loss of blood, and a whole new appendage is developed to replace the injured member. This accounts for the common sight of crayfish, etc., with one claw temporarily much smaller than its mate.

This reproduction of lost parts depends upon the degree of complexity of the part. The earthworm may be able to regrow the whole posterior part of its body while a starfish can develop all its organs if one ray and its base be left. The hydra and corals normally reproduce by budding off new individuals and the protozoa, simplest of all, regularly reproduce the whole animal by division in two parts. On the other hand,

higher forms, such as man, have tissues so highly specialized that we cannot even grow a new finger. The best we can do, is to develop scar tissue to fill a wound, or grow new hair, nails, skin, and (once only) teeth. This is one penalty for high specialization.

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SUMMARY OF CHAPTER XXII

CRUSTACEA

1. Characteristics.

- a. Two pairs of antennæ.
- b. Gills in most forms.
- c. Usually a cephalo-thorax.
- d. Limy external skeleton.

2. Crayfish (as type of crustacea).

- a. Structure.
  - (1) Exo-skeleton (for protection and to act as levers for muscles)
    - (a) Protective adaptations.
      1. Hard.
      2. Limy.
      3. Color.
      4. Spines.
      5. Projection over gills and abdomen
      6. Carapace.
      7. Rostrum.
    - (b) Lever adaptations.
      1. Hollow.
      2. Strong.
      3. Light.
      4. Hinge joints in all directions.

(2) Body regions.
  (a) Cephalo-thorax.
    1. Includes head and thorax.
    2. 13 segments.
    3. United for strength.
    4. Rostrum for protection.
    5. Carapace over anterior and gills.
  (b) Abdomen.
(3) Appendages.
  (a) Head appendages
    1. Sense organs.
      a. Antennules and antennæ (for feeling and smell).
      b. Eyes.
      c. Ear sacs.
      d. Sense hairs.
    2. Mouth parts.
      a. Mandibles (one pair, for chewing).
      b. Maxillæ (two pair, aid in holding food).
  (b) Thoracic appendages (gills on all thoracic appendages).
    1. Maxillipeds (three pair, holding and chewing food).
    2. Large claws (defence and food-getting).
    3. Clawed feet (two pair, locomotion and prehension).
    4. Unclawed feet (two pair, locomotion).
  (c) Abdominal appendages.
    1. Swimmerets (five pair for egg attachment in female).
    2. Tail fin (sixth pair) and telson (backward motion).
  (d) Study of appendages shows
    1. Modification of similar part, swimmeret, for different uses (homology).
    2. Adaptation for different functions (specialization).
    3. Division of labor among homologous parts.

b. Adaptations.
  (1) Locomotion.
    (a) Swimming backward by means of tail fin.
    (b) Walking either forward, backward, or sidewise.
  (2) Protection.
    (a) External skeleton.
    (b) Color.
    (c) Spines.
    (d) Carapace.
    (e) Projecting sides.
    (f) Speed.
    (g) Claws.
  (3) Food-getting (what food?)
    (a) Claws.
    (b) Speed.
    (c) Mouth-parts.
    (d) Senses.
    (e) Color.

- (4) Respiration (cf. protozoa and worms).
  - (a) Adaptations of gills for osmosis.
    1. Thin walled.
    2. Well supplied with blood.
    3. Protected.
    4. Large surface.
  - (b) Water current provided.
    1. Gill bailer.
    2. Locomotion backward.
    3. Leg motion in all directions.
- (5) Sensation.
  - (a) Eyes. (b) Feelers. (c) Hair.

3. Life history.

- a. Egg fertilized, attached to swimmeret (protection, aëration)
- b. Hatch in summer, remain attached to mother.
- c. Grow by moulting.
  - (1) Reason.
  - (2) Process.
    - (a) Absorption of lime from shell.
    - (b) Carapace splits.
    - (c) Water withdrawn from tissues, causing shrinkage.
    - (d) Humps out of shell.
    - (e) Re-absorption of water and rapid growth.
    - (f) Hasty formation of new skeleton.
- d. Top swimmers when young, then on bottom.
- e. Why so many eggs needed?

4. Reproduction of lost parts.

- a. What animals can reproduce lost parts?
- b. Why not so much in higher forms? (greater specialization).
- c. What tissues can man reproduce?

CHAPTER XXIII

INSECTA, A CLASS OF ARTHROPODS

Vocabulary

Trachea, a breathing tube, admitting air to the tissues. Plural: tracheæ.
Chitin, a horn-like, elastic substance found in the external skeletons of insects and other arthropods, pronounced "kite-in."
Accessory, additional or assistant organs.
Palpus, feeler or sense organ attached to the mouth parts of insects, etc. Plural: palpi.
Spiracles, external openings of the tracheæ, used in breathing.
Ganglion, a mass of nerve tissue. Plural: ganglia.

We are quite apt to refer to almost any small flying or crawling creature as a "bug." This is incorrect in two ways. A true bug is a member of only one division of insects. What we frequently call a bug may be some other insect, or even a spider or a centipede which are not insects at all. Do not speak contemptuously of "bugs," if you mean insects, for they are man's closest competitor for the food supplies of the world.

The Insects include that division of the Arthropods which have head, thorax, and abdomen separate, one pair of antennæ, three pairs of legs, usually two pairs of wings, and which breathe by means of tubes called tracheæ. This group includes more species than all the other living animals together, there being about four thousand kinds known already. Experts regard this as not more than one-fifth of all in existence. Not only are there many kinds of insects, but each kind produces myriads of individuals like the locusts and mayflies, whose swarms darken the sky. Their struggle for existence is very severe and this results in manifold adaptations of structure.

High Specialization. Highly specialized mouth parts for different kinds of food, wonderful leg and wing development for swift locomotion, marvelous instincts and complicated internal structure are some of the lines along which insects have developed in order to survive among their countless competitors in the race of life. Some are adapted for aquatic life, some take

refuge by burrowing, some live in colonies like bees and ants, others fight their battles alone; some have become swift in running, leaping, or flight, while others have fallen back on parasitic laziness.

Classification. We cannot study all, or even one species thoroughly. However the accompanying table will show the names and representatives of a few of the sixteen different orders, and then we shall take up two or three types in greater detail.

Order	*Representative*
Orthoptera	grasshopper—cricket—locust
Pseudo-neuroptera	dragon-flies
Hemiptera	true bugs—lice—scale insects
Diptera	flies—mosquitoes—fleas, gnats
Coleoptera	beetles
Lepidoptera	moths—butterflies
Hymenoptera	bees—ants—wasps

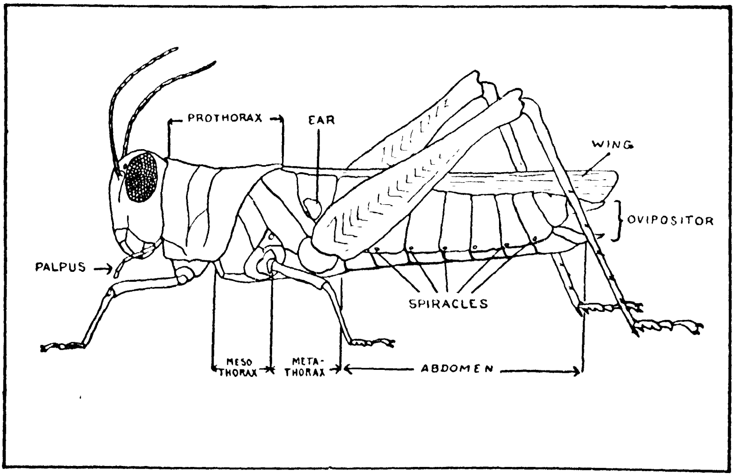
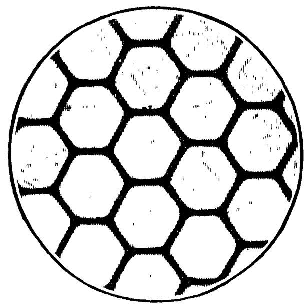


FIG. 71. Grasshopper (locust), showing the external parts which may be seen without a lens.

The Grasshopper. The grasshopper (which really is a locust) will be taken as a type of all the insects. It belongs to the order Orthoptera, which means "straight winged" and refers to the narrow folded wings, held straight along the body.

Exo-skeleton. As in all Arthropods, the skeleton is external, but differs from the crayfish in that it contains no lime. It consists entirely of a light, tough and horny substance called *chitin* which is usually protectively colored. The head, with its sense organs and mouth parts, the thorax with its legs and wings, and the abdomen, with the vent and reproductive organs, are all readily distinguished.

Sense Organs. The antennæ are the most anterior appendages, and, as usual, are many jointed and devoted to the senses of touch and smell. There are two kinds of eyes, three simple ones located respectively at the base of each antenna and on the ridge between them, and the large compound eyes projecting from the sides of the head and covered by hundreds of six-sided lenses. The shape, location, and number of lenses in the eye seem to adapt the insect for sight in several directions at once, but the image formed cannot be very sharp.



From Kellogg.

FIG. 72. Part of compound eye of a horsefly, showing hexagonal lenses. Greatly magnified.

Mouth Parts. The mouth parts of the grasshopper are fitted for biting and chewing hard foods and consist of labrum, mandibles, maxillæ, and labium, named in order from the anterior. Though the mouth parts of insects are greatly modified to suit all kinds of food, still these four sets of organs are usually present, so we must become familiar with their names and appearance.

The labrum is the two-lobed upper lip which fits over the strong, toothed, horizontal jaws or mandibles. The pair of maxillæ, or accessory jaws, are next behind the mandibles. They aid in cutting and holding food, and also have a sense organ, like a short antenna. This is called a palpus (plural: palpi). Posterior to the maxillæ comes the labium or lower lip, a deeply two-lobed organ, also provided with palpi, which aids in holding food between the jaws.

Thorax. The thorax consists of three segments, the pro-, meso- and meta-thorax. The prothorax is a large saddle-shaped segment to which the head is attached and bears the first pair of legs; the middle or mesothorax bears a pair of legs and the first pair of wings; the last segment (metathorax) bears the leaping legs and the last pair of wings.

Legs. Each of these six legs consists of five parts or segments, connected by strong joints and adapted for locomotion by walking. The posterior pair is enormously developed for leaping also. The feet (tarsi) are provided with spines, hooks, and pads to give firm grip when jumping or crawling. A joint near the body almost like a "ball and socket" permits sufficient freedom of motion.

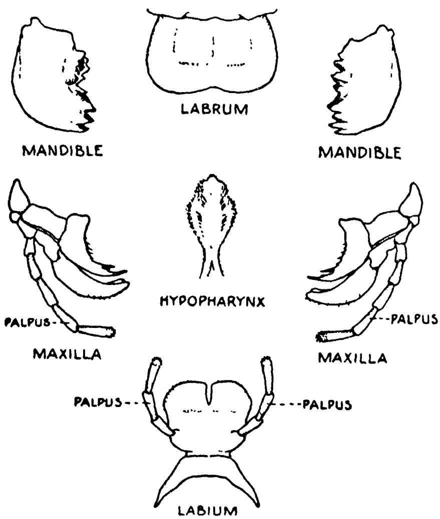


FIG. 73. Mouth parts of the grasshopper.

Wings. The anterior (mesothoracic) wings are long, narrow, and rather stiff. They protect the more delicate

The upper lip or labrum is a thin scoop-shaped organ, which helps to hold food between the jaws.

The mandibles or jaws, are very thick at the edge, sharply toothed and operated by powerful muscles. They are dark brown in color and hard enough to gnaw dry wood.

The maxillæ or accessory jaws are very complicated organs consisting of two sharp hook-shaped parts backed by a sort of hood. These help in holding food and perhaps in chewing it, too. Back of the hood are the palpi, whose tips bear sense hairs, and perhaps enable the grasshopper to judge of the kind of food he may be eating.

The "tongue" or hypopharynx in the centre, fits closely in the throat and seems to act as a sort of piston in helping to suck in the food particles.

The labium or lower lip, like the upper one, helps hold the food in place, but is much larger and has a pair of palpi, like those on the maxillæ.

Such mouth parts are typically for biting and chewing and are similar to those found in many beetles, also.

under wings and act as planes in aiding flight and leaping. The posterior (metathoracic) wings are thin and membranous. They are supported by many veins and, when not in use, refolded lengthwise, like a fan, beneath the narrower anterior wings.

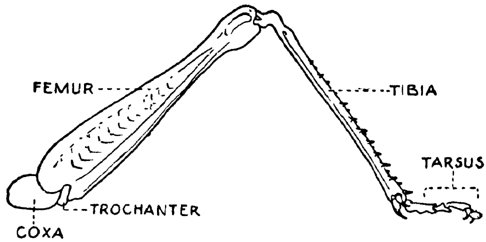


FIG. 74. Posterior leg of grasshopper, showing structure and adaptations for leaping.

The two short segments next the body are called the coxa and trochanter. Their function is to give freedom of motion to the base of the leg and to set it out a little from the side of the body so that it can push directly backward in jumping.

The thick part is the femur and contains some very powerful muscles, though the body muscles also help in jumping.

The tibia is the long thin part and is provided with backward projecting spines which prevent back sliding and aid in climbing through grass.

The foot consists of several tarsal joints with flexible pads and backward projecting spines which prevent slipping just like the spiked shoes of the human jumper. The claws at the end aid in this and also in climbing.

The knee and ankle joints move only in one plane, but the joints next the body can move sidewise also.

Abdomen. The abdomen consists of ten segments, each composed of an upper and lower part, united by a membrane which allows it to expand and contract in the process of breathing. There are no jointed appendages as on the head and thorax, but eight of the segments have breathing pores (spiracles) on each side. The segment next to the thorax bears the ears which are large membrane-covered cavities.

The extreme posterior segments in the female bear two pairs of hard and sharp-pointed organs called ovipositors (egg placers) whose function is to dig a hole in the ground in which the eggs are laid. The males have no such organs but the posterior of the abdomen is enlarged and rounded upward.

Active Life. The activity of insects is well known but little appreciated. They have the most enduring and powerful

muscles of any animal, in proportion to their size. Think of the long swift flight of bees, often extending for miles, at enormous speed; think of the loads carried by ants and beetles; of the hard labor done by boring and burrowing insects,—then compare their size and weight with our own and see how fast we ought to fly or run, how far we should jump, or how much we should carry, if we had their muscular ability. Of course their enormous activity requires a great deal of energy which means that they must use a large amount of food, and this, in turn, implies a complete digestive apparatus. The digested food requires oxygen to oxidize it and liberate its energy and this requires a perfect system for breathing to supply the oxygen. To control such a powerful high-speed engine, a well-developed nervous system is also demanded.

The foregoing sounds like the "House that Jack Built" but is an outline of just what we find to be the case, not only in insects but in all higher forms. It is merely another instance of our order of study, "Structure, Function, Adaptation."

Internal Structure. The internal structure is very complex, some insects having over twice as many separate muscles as we have in our whole body. The digestive system is well developed, there being salivary glands, a crop, stomach, digestive glands, intestine, and rectum.

Excretion is provided for by a large number of thread-like tubes at the junction of stomach and intestine. Circulation, while not entirely inclosed in blood vessels, is controlled by a six-chambered heart on the dorsal (upper) side, from which the light-colored blood is forced toward the head and around throughout the tissues, in contact with the air tubes.

Respiration. The respiratory system is highly developed. It consists of an extensive network of air tubes called tracheæ. There are six main tubes running lengthwise, from which branch smaller tracheæ to every tissue in the body.

These tracheæ open by means of the spiracles, which are tiny holes, protected from dust by hairs, found on the abdomen (8 pairs) and on the thorax (2 pairs). By alternate expansion and contraction of the segments at the rate of sixty-

five per minute air is pumped in and out of these spiracles, and circulates through the tracheæ, where, by osmosis, the oxygen from the air and carbon dioxide from the blood exchange places. A peculiar feature of the insect respiration is the fact that the air goes to the blood by means of the tracheæ instead of the blood going to the air in capillaries as in our lungs. Another curious fact is that the veins of the wings are probably tracheæ, adapted for the function of support rather than respiration.

Nervous System. The nervous system of insects reaches a higher degree of development than that of any invertebrate group and a comparison of the types studied can well be made at this time.

The *protozoan* cell received its impressions directly. It responded throughout, to heat, light, contact, and possibly other stimuli, but vaguely and without the aid of any nervous tissue.

In animals like the *hydra*, certain groups of cells seem more sensitive than others to external influences and also appear to control the activities of the animal. These are the simplest examples of a nervous system and might be regarded as unconnected nerve ganglia.

In earthworms each segment has its nerve mass or ganglion, but all are connected by a nerve and each sends out many branches to various organs. Then, too, in the worms, there is a larger ganglion in the anterior end, above the mouth, which sends special nerves to the mouth parts and skin. Although there are no special organs of sensation, and the structure is very primitive, there is, nevertheless, an organ corresponding to a brain.

In the *crustacea*, the head ganglion, or brain, is located at the base of the rostrum. It is much larger than in worms and has nerves extending to the eyes, "ears," antennæ, and mouth parts. This brain is connected with ganglia along the under side of the body but instead of having one for each segment, as in the worms, they are combined into eleven larger and more complicated nerve masses.

In the *insects* this combination of ganglia has gone farther still. Including the brain there are two ganglia in the head, three in the thorax, and five in the abdomen, and the brain and sense organs are much more specialized in function.

If we could study more kinds of animals we would observe this general tendency toward increasing the development of the head ganglia, of combining others and reducing their number while increasing their ability, and the development of more efficient sense organs and greater motion control.

As soon as the simplest animal forms developed far enough to have one end always go forward (anterior) in locomotion, then that end, naturally, "ran into" contact with its environment. So, at the anterior end the sense organs could be most useful, which is the reason for this headward tendency in development.

In all animals the nervous system performs two general functions; it receives and appreciates impressions from without (sensation), and causes and controls motions from within (motor impulses). As the animals increase in complexity, the nervous system correspondingly develops. As the complexity increased, there was greater need of one controlling region, so that all the body's numerous functions could operate in harmony and as a result the need of a brain developed. Its location, as explained above, was almost of necessity in the "head" or anterior end of the animal.

Life History. The eggs are fertilized internally, and are deposited in two masses, protected by a gum-like substance, in holes which the female digs in the earth with her ovipositor. From twenty to thirty eggs are thus deposited in the fall, and hatch the following spring. This illustrates a twofold advantage of egg reproduction, for, not only is the number of individuals increased, but they pass the winter safely in the protected egg, while most of the adults are frozen to death. The young (nymph), though small, red, and wingless, still resembles the adult in most respects, but as is often the case with the young, the head is disproportionately large. As with all arthropods, they grow by moulting, usually five times, and at each step, develop in size and wings till they reach full growth. The

moulting, which takes about half an hour, is followed by rapid growth and formation of a new exo-skeleton, the former one having split along the thorax to allow the exit of the growing insect. It emerges head first but very weak and limp, and often does not survive the process.

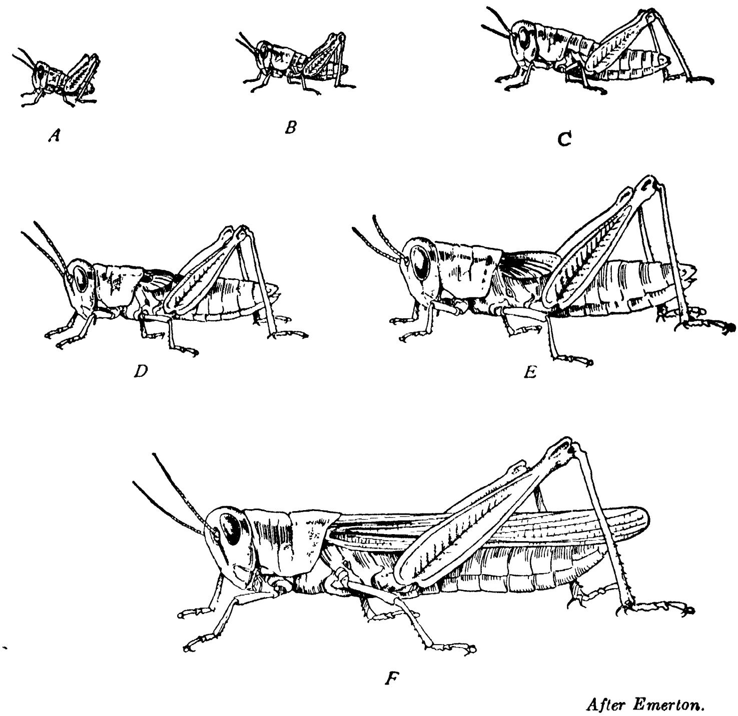


FIG. 75. Stages in the development of locust ("grasshopper"). *A.* Just hatched, without wing pads;—head large in proportion. *B.* After first moulting. *C.* After second moulting, showing beginning of wing pads. *D.* After third moulting, wings and body developing. *E.* After fourth moulting. *F.* Adult with fully developed wings.

Metamorphosis. In many animals the development from egg to adult passes through more or less distinct stages instead of being a gradual increase in size. Such a life history is called a metamorphosis.

Among insects these stages may be several in number and

the differences between them slight, as in the grasshopper, or there may be four definite and distinct stages, the egg, larva, pupa, and adult as found in the butterfly, for example. The former type is called an *incomplete* metamorphosis, the latter a *complete* metamorphosis.

From Pearse.

FIG. 76. Events in the life of the grasshopper. *A*, captured by robber fly; *B*, flying; *C*, dead from fungous disease; *D*, caught by a spider; *E*, laying eggs; *F*, captured by digger wasp;—*G*, *H*, *I*, stages in growth of young.

Economic Importance. The members of the order (orthoptera) to which the grasshopper belongs are, with one exception, all harmful to man. Their food is mostly cereal grains or crop plants, which they often destroy over wide areas. Locusts and grasshoppers have been a plague since ancient times. They are often referred to in Scripture and the second chapter of Joel contains a very vivid description of the destruction wrought by a swarm of locusts. The only useful relative is the mantis, which is carnivorous and eats other insects, many of which are harmful.

COLLATERAL READING

Life History of American Insects, Weed, pp. 67–81; *Insect Book*, Howard, pp. 334–340; *Insect Life*, Comstock, pp. 70–233; *Manual of Insects*, Comstock, pp. 104–118; *Guide to Study of Insects*, Packard, pp. 556–572; *Lessons in Zoölogy*, Needham, p. 48; *Textbook of Zoölogy*, Parker and Haswell, Vol. I, p. 584; *Textbook of Zoölogy*, Packard, p. 308; *Animal Forms*, Jordan and Kellogg, p. 117; *Animal Life*, Jordan and Kellogg, p 234; *Textbook of Zoölogy*, Linville and Kelly, pp. 11–14; *Elementary Zoölogy*, Kellogg, pp. 161–163; *Injurious Insects*, Treat, p. 269; *Injurious Insects*, Saunders, p. 157; *Introduction to Zoölogy*, Davenport, pp. 1–4; *Economic Zoölogy*, Smith, pp. 11–51, 79–100; *Economic Zoölogy*, Kellogg and Doane, pp. 14–25; *Descriptive Zoölogy*, Colton, Chaps. I–III; *Practical Zoölogy*, Davidson, Chaps. II–VII; *Farm Bulletins*, Nos. 47, 59, 70, 80, 132, 209, 211, 247, 264, 284; *Practical Zoölogy*, Hegner, pp. 8–23.

SUMMARY OF CHAPTER XXIII

INSECTS

1. Characteristics.
- a. Separate head, thorax, and abdomen.
- b. One pair antennæ, three pair legs.
- c. Usually two pair wings.
- d. Breathe by means of tracheæ.

2. Specialization.
- a. Reason.
  - (1) The best adapted survive.
    - (a) Severe struggle for existence.
      - 1. Large number of kinds and individuals.
- b. Specialization for various foods.
  - (1) Vegetable foods (grasshopper, biting).
  - (2) Blood suckers (mosquitoes).
  - (3) Sap suckers (bugs and scale insects).
  - (4) Scavengers (flies and beetles).
  - (5) Nectar (bees and moths).
- c. Specialization for locomotion.
  - (1) Crawling (beetles, etc.).
  - (2) Flying (bees, etc.).
  - (3) Jumping (grasshopper).
  - (4) Swimming (beetles and some bugs).
  - (5) Water surface (striders).
  - (6) Burrowing (ants, etc.).

3. General structure.
- a. Exo-skeleton.
  - (1) Chitin.
  - (2) Light.
  - (3) Strong.
  - (4) Protective coloration.

b. Regions.
- (1) Head (for sense and food-getting organs).
  - (a) Antennæ.
    - 1. One pair.
    - 2. Functions (cf. crayfish).
  - (b) Eyes.
    - 1. Simple.
      - a. Three. b. Location.
    - 2. Compound.
      - a. Structure. b. Why not on stalks?
    - 3. Mouth parts (biting).
      - a. Upper lip (labrum, for holding food).
      - b. True jaws (mandibles, for chewing).
      - c. Accessory jaws (maxillæ, to aid jaws) (palpi).
      - d. Lower lip (labium, to hold food) (palpi).
- (2) Thorax (for locomotion, respiration).
  - (a) Anterior thorax (prothorax).
    - 1. Movable. 2. Legs attached.
  - (b) Middle thorax (mesothorax).
    - 1. Strong.
    - 2. Wings and legs.
  - (c) Posterior thorax (metathorax).
    - 1. United to mesothorax wings and jumping legs.
  - (d) Legs.
    - 1. Functions.
      - a. Walking. b. Clinging. c. Leaping.
    - 2. Structure.
    - 3. Adaptations.
      - a. Strength of muscles d. Spines, pads, etc.
      - b. Length of leverage e. Point of attachment.
      - c. Free backward movement.
  - (e) Wings.
    - 1. First pair.
      - a. Planes d. Stiff.
      - b. Protection e. Straight.
      - c. Concave.
    - 2. Second pair.
      - a. Thin. c. Propellers.
      - b. Folded fan-wise.
- (3) Abdomen (for reproduction, breathing, hearing, etc.).
  - (a) Structure.
  - (b) Adaptations.
    - 1. Spiracles and motion of segments (respiration).
    - 2. Ovipositors (reproduction).
    - 3. Ears (hearing).

4. Internal structure.

a. Muscles.
- (1) Complex. (3) Very numerous.
- (2) Strong.

b. Digestion.
  (1) Glands.
  (2) Crop.
  (3) Stomach.
  (4) Cæca.
  (5) Intestine.
  (6) Rectum.
c. Excretion.
  (1) Malpighian tubes.
d. Circulation.
  (1) Open system.
  (2) Dorsal.
  (3) Light colored blood.
e. Respiration.
  (1) Spiracles.
  (2) Trachea.
  (3) Motion of abdomen.
f. Nervous system.
  (1) High development.
  (2) Senses well developed.

5. Life history.
a. Fertilized egg.
  (1) Buried in earth by ovipositors.
    (a) 20–30 in two masses.
    (b) In autumn.
  (2) Functions.
    (a) To reproduce.
    (b) To pass winter protected.
b. Nymph.
  (1) Like adult, but small and wingless.
  (2) Growth by moults.
  (3) Development of wings.

6. Metamorphosis.
a. Complete.
b. Incomplete.

7. Economic Importance.

8. Evolution of the nervous system.
1. Development.
  a. Protozoa.
    (1) Direct to protoplasm.
    (2) Sense heat, light, and contact.
  b. Hydra.
    (1) Special nerve cells.
    (2) Motor control.
  c. Worms.
    (1) Ganglia *connected.*
    (2) Beginning of ***brain.***
  d. Crustacea.
    (1) Fewer ganglia.
    (2) Cephalization.
    (3) *Sense organs.*
  e. Insecta.
    (1) Well-developed brain ganglia.
    (2) Great motor control.
    (3) *Instinct.*
2. General tendency of nervous development.
  a. Fewer ganglia.
  b. Increasing complexity (centralizing control).
  c. Location in anterior (first contact with environment).
3. General functions of nervous system.
  a. To receive impressions from without (sensation).
  b. To control and originate motion (motor impulses).

CHAPTER XXIV

INSECTA, CONTINUED

Vocabulary

Vestiges, remnants or traces of organs.
Communal life, life in colonies for mutual help.
Gorged, filled with food.

Bearing in mind the fact that all insects have, in general, the same organs as those found in the grasshopper, we shall now briefly study how they are developed in representatives of a few other insect orders.

LEPIDOPTERA

The *butterflies* and *moths* belong to the order lepidoptera (scale winged) and furnish a familiar type of quite a different group of insects.

Head. The antennæ of butterflies are club shaped or knobbed at the tip while those of moths are usually feather like. The

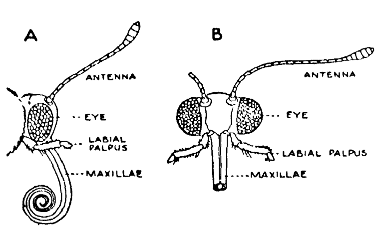


FIG. 77. Head and mouth parts of butterfly. A. Side view of head.—The enormous eyes curve out so far that vision is possible in all directions. The small organs below the eyes are palpi from the labium, which are also sense organs. The partly uncoiled "tongue" is composed of the two maxillæ, and has a roughened tip for opening the nectar glands of flowers. It is called the proboscis. B. Front view of head.—Same parts shown as mentioned above except that the proboscis has been cut through to show the two maxillæ, joined edge to edge with the tube between them for sucking nectar.

compound eyes are very large and rounded and the neck very flexible, but it is in the mouth parts that they differ most from the orthoptera, these being adapted for sucking nectar from flowers. The labrum and mandibles are reduced to mere

vestiges. The maxillæ are enormously lengthened and locked together to form the coiled proboscis or tongue which, when extended, may equal in length all the rest of the body. It is always long enough to reach the nectar glands of the flowers they prefer. The labium is reduced in size, two feathery palpi being all that is left of it in most cases. In this set of mouth parts, we have an example of organs homologous to those of the grasshopper, but adapted for very different functions.

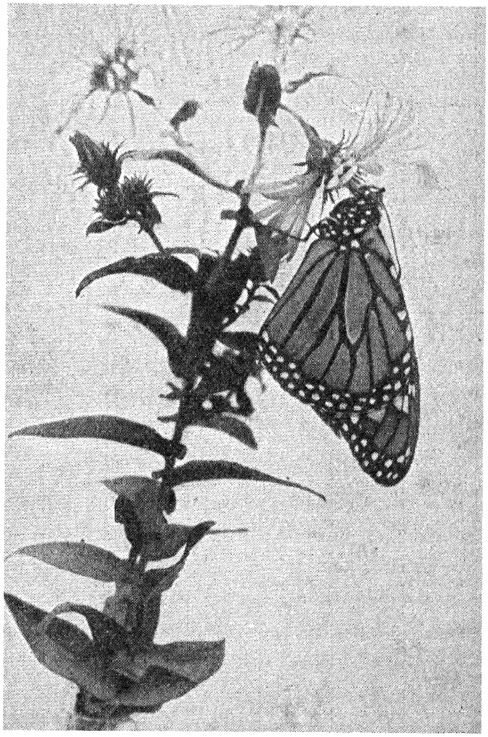


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FIG. 78. Monarch butterfly.

Thorax. The legs of the lepidoptera are small and weak, but have the same general structure as in all insects. Obviously the butterfly neither runs nor jumps. It uses its legs only for clinging to its resting places and spends much of its time in the air. The wings are large and covered with colored scales from which the order gets its name. These scales help the few veins in giving strength to the wing, and in some cases aid in color protection as well. The thorax and its muscles which move the wings are not very powerful, and the butterfly, though easily supported by its large wing spread, is not a swift flyer.

Abdomen. The abdomen resembles that of the grasshopper, but has fewer visible segments, and as in all insects is the least specialized body region.

Life History. The eggs of most lepidoptera are deposited on or near the plant which will be the food of the young. Some pass the winter in this stage but usually eggs are deposited in the spring and develop into a caterpillar the following summer.

The egg does not hatch into a form at all resembling the adult, but instead, there emerges a tiny worm-like form called the *larva,* which differs entirely in structure, having no wings, nor compound eyes, but possessing several extra pairs of legs and biting mouth parts. In fact, these and other insect larvæ are what we often call "worms," which they do somewhat resemble in shape. However, they are really one step in the development of an insect, and are vastly more complex than the true worms. The larval stage devotes its whole attention to eating, growing, and moulting. After about five changes of clothing, it stops this gluttonous life in which it often does a great deal of harm, and goes into a resting stage called the *pupa.*

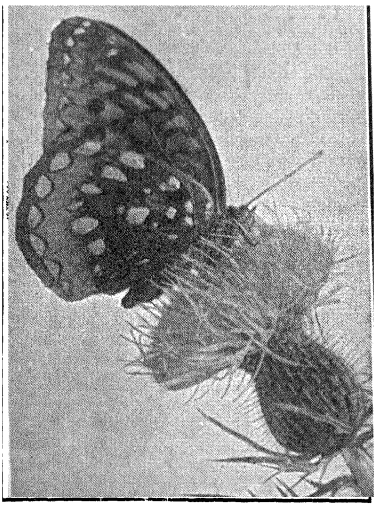

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FIG. 79. Arginnis Cybele.

A silkworm, during its thirty-day period of growth, increases its weight 15,000 times. At this rate a seven pound baby would weigh 3500 pounds when two days old and at one month, would reach the tremendous total of fifty tons. With such rates of growth, it is not strange that caterpillars need enormous quantities of food and so do great damage when they feed on man's crops.

In butterflies the pupa is called a chrysalis, and is protected by a hard membranous covering during its long pause. The larva often seeks a protected spot before this change occurs.

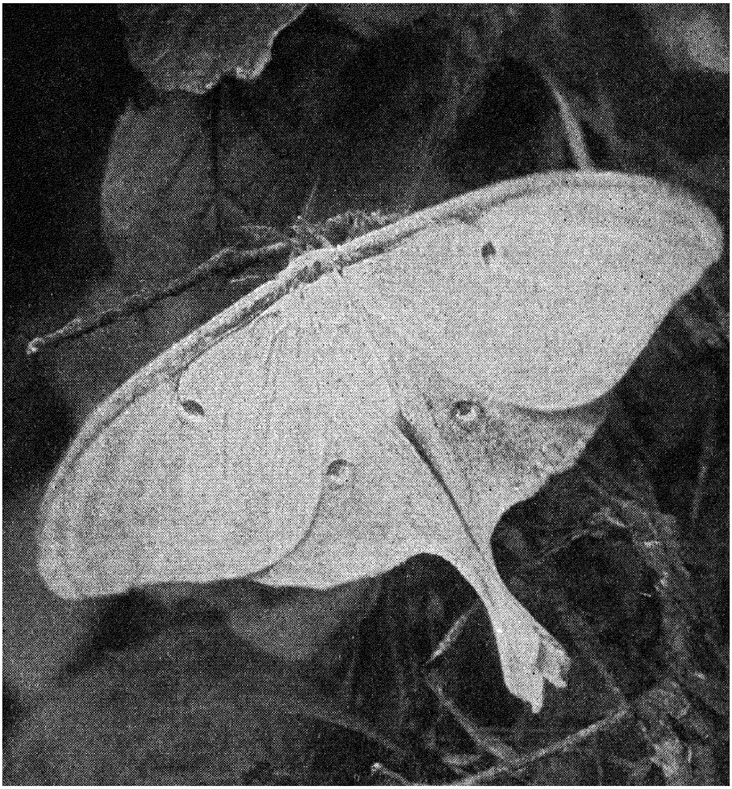

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FIG. 80. Luna moth, female.

The moth larva, on the other hand, often spins a wonderful case of silk, the *cocoon*, by which it protects and attaches its pupa for its period of retirement. This pupa stage in which the lepidoptera usually pass the winter, is not really a period of entire rest. Marvelous changes take place which are not well

understood, but this at least is known, the worm-like larva emerges totally changed both in internal and external structure, as the *adult* butterfly or moth.

Whereas the larva's function was to eat and grow, the adult eats only the nectar of the flowers and its life work is to produce or fertilize the eggs for the next generation.

Such a life development, consisting of distinct stages, is called complete metamorphosis, as distinguished from a life history of gradual changes (like the grasshopper) which is called incomplete metamorphosis. Complete metamorphosis is not confined to the lepidoptera. The bees, beetles, and flies all pass through similar series of changes which can be tabulated as follows:

Egg	Deposited near source of food Period of increase in number
Larva	Period of eating and growth (often harmful) Worm, grub, or maggot stage
Pupa	Period of quiet, internal transformation Usually pass winter in this stage May have cocoon
Adult—Reproductive stage	

Economic Importance. The larva of the lepidoptera is often very harmful because it feeds on man's crops, the multitude of so-called "worms" being only too familiar examples. The pupa stage of the silk moth furnishes us with silk from the threads of its cocoon. The adults aid in the pollination of flowers, by reason of their thirst for nectar and their hairy bodies which carry the pollen.

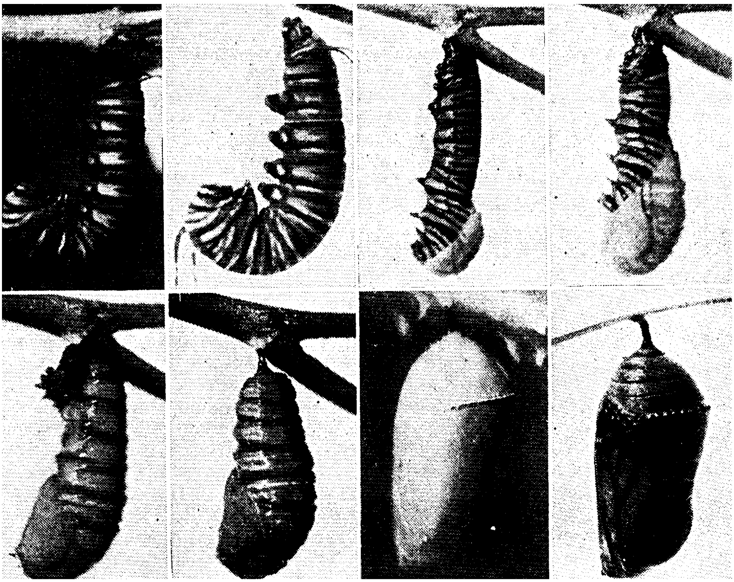
Comparison of Moth and Butterfly. Moths and butterflies are often confused, but can usually be distinguished by the following comparison:

Butterfly	*Moth*
Day flier	Night flier
Chrysalis	Cocoon
Wings vertical when at rest	Wings held horizontal
Antennæ knobbed	Antennæ feathery
Abdomen slender	Abdomen stout

Protective Coloration. Animal often resemble their surroundings. Birds like the snipe, meadow lark, and quail, mammals like the rabbit and field mouse, so harmonize with the dried

grass and brush amid which they live, that it is difficult to see them when they are at rest. The humble toad resembles the brown earth around him, the frog is like his green and mottled background.

There are also animals that change color with the season and so harmonize with two sets of surroundings. Such are the



Courtesy of the American Museum of Natural History.

FIG. 81. This caterpillar of the monarch butterfly is ready for the metamorphosis. It hatched in late summer and grew for two weeks. It stopped eating, chose a secure spot and spun a small thick carpet of silk. It walked over this until the hind feet were entangled in the silk, then it hung head downward, motionless. The skin now loosens, and after twenty-four hours splits over the head. At this stage the caterpillar, by muscular contraction works the skin off upward into a small shriveled mass; then during the few seconds longer that it still remains attached to the skin, it reaches out its slender end and with great effort and force pushes it up into the silk carpet. The whole process has taken but three or four minutes. Slowly the shape changes, the segments above contracting, the form rounding out; and behold an emerald-green chrysalis studded with golden spots! In two weeks the pattern of brown and orange wings begins to show through, finally the chrysalis skin splits over the head, and the butterfly crawls out.

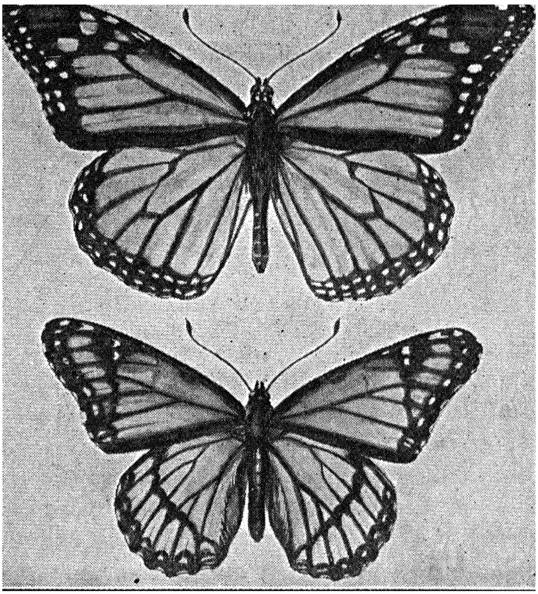
weasels, hares, and ptarmigans. The white of arctic animals may also give warmth as well as color protection.

From Kellogg.

FIG. 82. Protective resemblance as shown by the "dead leaf" butterfly.

Color protection is especially evident among insects and their larvæ. Many are green like the grass and leaves among which

they live. This is often due to the chlorophyll of their food showing through their delicate tissues. Others are colored like dead leaves, flowers, or bark—whichever may be their usual background. The common brown locust ("grasshopper") resembles the dry ground on which it alights. The walking stick insect looks so much like the small twigs among which it lives that it can hardly be found.



From Kellogg

FIG. 83. Mimicry as shown by the viceroy butterfly (lower), which resembles the monarch (above) closely enough to be avoided by birds which have found the latter bad tasting.

Mimicry is color protection carried to such a degree that one form resembles, not the background, but some other particular object. Butterflies afford the best examples of mimicry. The leaf butterfly bears a startling resemblance to a dead leaf; color, veins, shape, and position when at rest all contribute to the similarity.

The viceroy butterfly much resembles the monarch species. This may possibly be of use since the latter is protected by a bad taste and birds do not eat it. Perhaps they are deceived by the similar looks of the viceroy and leave him alone.

Color resemblance may aid in attack as well as escape from attack. Many animals that stalk their prey are colored like their surroundings and thus are not seen by their prospective victim; the tiger, leopard, and jaguar crouch unseen in the jungle, their spots and stripes closely resembling the light and shade of their background; and the lion of the desert wears khaki to help in stealing upon his quarry.

Too much importance must not be attached to color protection, even among insects, where it appears to be most developed. This applies especially to mimicry which, while interesting, is not easily accounted for wholly on a basis of protection. Certainly it is not due to any effort on the part of the animal to imitate his surroundings.

Hymenoptera

The order hymenoptera (membrane winged) which includes the bees, ants, and wasps, represents the most highly specialized type of insect. In structure, instincts, and manner of life the hymenoptera far excel all their relatives. A complete account of the doings of some of the higher forms makes a common fairy tale seem credible by comparison. Huxley said that an ant's "brain" was the most wonderful piece of protoplasm in the world, and this would apply almost equally to several other representatives.

Honey Bee. As an example of this order we shall study the honey bee, since it is a form with which all are familiar. The body regions are very distinct, the head is attached to the thorax by a flexible neck and the thorax to the abdomen by a slender waist. Each region is highly developed.

Head. The sensitive, elbowed antennæ, the enormous compound eyes and three simple eyes are easily seen, but the mouth parts are very complicated and are really a set of tools by themselves. The *labrum* is small, but the *mandibles* are developed

into efficient cutting and biting organs. They are used in manufacturing wax into cells. The *maxillæ* are complicated organs adapted also for cutting and piercing as well as aiding in the work of the labium. The *labium* and its palpi form a very efficient "tongue" for lapping up the nectar upon which they live.

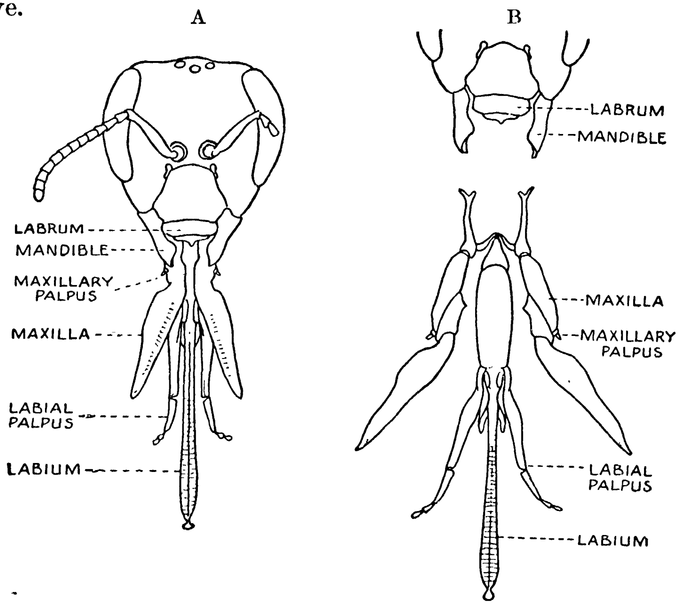


FIG. 84. Mouth parts of the honey bee. Shown in place in A and separated in B.—The mouth parts as a whole are fitted for biting, cutting, and lapping liquids.

The labrum is reduced to a small triangular organ, of slight importance except as a guide for the other parts.

The mandibles are powerful, sharp-edged jaws with which wax or leaf material can be cut and worked.

The maxillæ are slender, pointed organs which can also be used for cutting and working in wax.

The labium is the most highly modified of the mouth parts, and is used for lapping up nectar from flowers. For this purpose it is long, slender, and flexible, with roughened tip to hold more liquid. The labial palpi are attached at the side and are probably sense organs.

As a whole the bee mouth parts present a very high example of specialization, in which the usual six parts are developed to a condition little resembling the typical condition in the grasshopper.

Resulting from this, the bee can do several different operations with its mouth parts, while in most cases they would be fitted only for one, such as biting in the case of the grasshopper, or piercing in case of the mosquito.

Thorax. The thorax is large, strong, and provided with powerful muscles which operate the legs and wings.

The bees are notably swift and enduring flyers and their wings, while small, are exquisitely proportioned and operate at very high speed, producing the familiar hum. The anterior wing is much the larger and the posterior wing may be attached to it, in flight, by tiny hooks. Honey bees often wear out their wings by constant use.

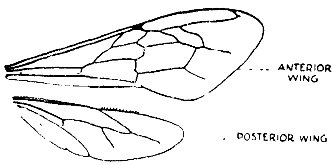


FIG. 85. The wings of the honey bee.—Attention is called to the relatively small size and fewness of veins in the bee wings. This is evidence of high specialization, as they are perhaps the most efficient flying apparatus possessed by any insect, yet are comparatively small and light. The few veins are placed in exactly those regions where strain is greatest, the wing muscles are powerful, and the wings operate at a high rate of speed, which accounts for their small size. The posterior pair bears a series of hooks which may attach it to the anterior pair, so that both act as one wing in flight, but fold back separately when at rest.

The three pairs of legs are each provided with special adaptations. On the anterior pair is found a notch and comb through which the antennæ are drawn to clean them of pollen. The middle pair have a spine or spur which is used in transferring pollen back to the hind legs which are most highly specialized of all. This pair has one segment bordered with strong hairs to form a basket for carrying pollen. The next segment has a series of combs for handling it, and between the two segments is a movable notch which is used as a shear for cutting and shaping the wax.

Abdomen. The abdomen consists of six segments, with ovipositor or sting at the posterior end. Only in the queen is the ovipositor developed as a true egg-laying organ. The worker bees, which are undeveloped females, produce no eggs and have the ovipositor modified into the well known "sting." This is a complicated organ consisting of two barbed darts operated by strong muscles and enclosed in a sheath. The darts are connected with a gland which secretes the poison and makes a bee sting so painful. On the four last abdominal segments of the workers are glands which secrete the wax used in comb making.

Life History. The life history of the honey bee is a fine example of communal life and mutual help. Each member of the colony works for the good of all, and this habit has resulted in great success as a whole, as well as remarkable development for each individual. There are three forms of bees in any colony, the queen, drones, and workers.

The Queen. The queen is almost twice as large as the worker, with a long pointed abdomen, but with no pollen basket nor comb. Her particular function is the production of eggs to continue the colony. She may produce as many as three thousand per day, which is twice her own weight. The queen develops from an ordinary egg, but the workers enlarge the wax

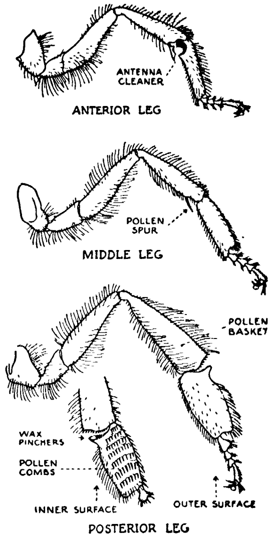


FIG. 86.

The legs of the honey bee, showing structure and adaptations.

Notice that in all the legs there are the same number of segments, but differently developed. This is an excellent example of division of labor or specialization among homologous parts.

The anterior leg has, at the first tarsal joint, a notch and a movable spine over it, so that the antennæ may be drawn through and cleaned of pollen after visits to the flowers. When you realize that the antennæ are the insect's most important sense organs, except possibly the eyes, this is seen to be an important special function.

The middle leg is only slightly modified, but has a strong spine which is used in passing back the pollen from the other legs and depositing it in the pollen baskets.

The posterior leg, of which both surfaces are shown, is most highly specialized. Along the edges of the tibia are developed strong rows of hairs which form a pocket or basket, in which the pollen is carried.

The joint between the tibia and the first tarsal segment is shaped like a pair of shear jaws, and is used for wax working.

The first tarsal segment is provided with rows of stiff hairs which help to comb the pollen into the baskets, or from the opposite legs.

The rest of the tarsal segments are developed as usual, for clinging in locomotion, in the case of all three sets of legs.

In the bee, then, there are at least six different functions performed by the legs, for which they are provided with special structural adaptations.

Such high development is probably the result of the habit of communal life which permits greater division of labor than is possible where animals live alone or in pairs.

cell in which it is to grow and feed the grublike larva with extra portions of nourishing food. This causes the development of a queen, or fertile female, instead of a worker, which is a female without the ability to lay eggs. After being thus fed for five days, the larva weaves a silken cocoon, changes to a pupa, and is sealed into her large waxen chamber by the workers. When the mature queen emerges from her cell, she seeks out other queen larvæ in the colony and kills them, or if she finds another adult queen, they fight till one is killed. She never uses her sting except against another queen.

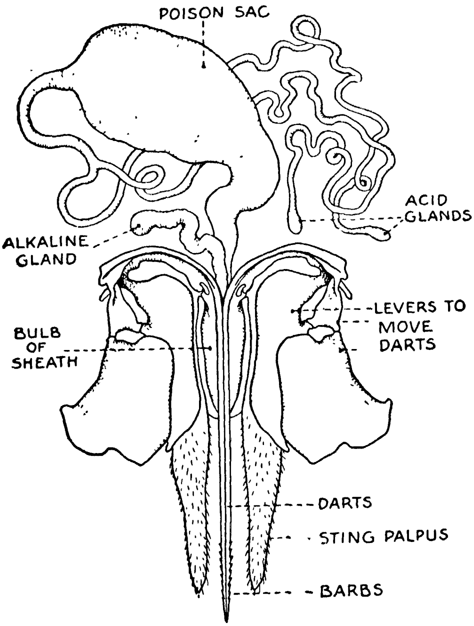


FIG. 87. The complicated structure of the bee sting.

If the workers prevent her from destroying the other queens, she takes with her from two to twenty thousand bees and "swarms" out to seek a home elsewhere. In this way new colonies are formed and overcrowding is prevented.

After a few days she takes a wedding flight in the air where she mates with a drone or male bee. Then she returns to the hive and begins her life work of laying eggs. This is no small task as one queen may produce as many as one million eggs per year and often lives from two to five years. Although we call her a "queen" she is in no sense the ruler of the hive but rather its common mother.

The Drones. The drone, while larger than the worker, is

smaller than the queen and has a thick, broad body, enormous eyes, and very powerful wings. It is not provided with pollen baskets, sting, or wax pockets. His tongue is not long enough to get nectar, so he has to be fed by the workers and his sole function is to fertilize the eggs of the queen. However, this easy life has its troubles for with the coming of autumn when honey runs low, the workers will no longer support the drones, but sting them to death, and their bodies may be found around the hives in September. There are only a few hundred drones in each swarm.

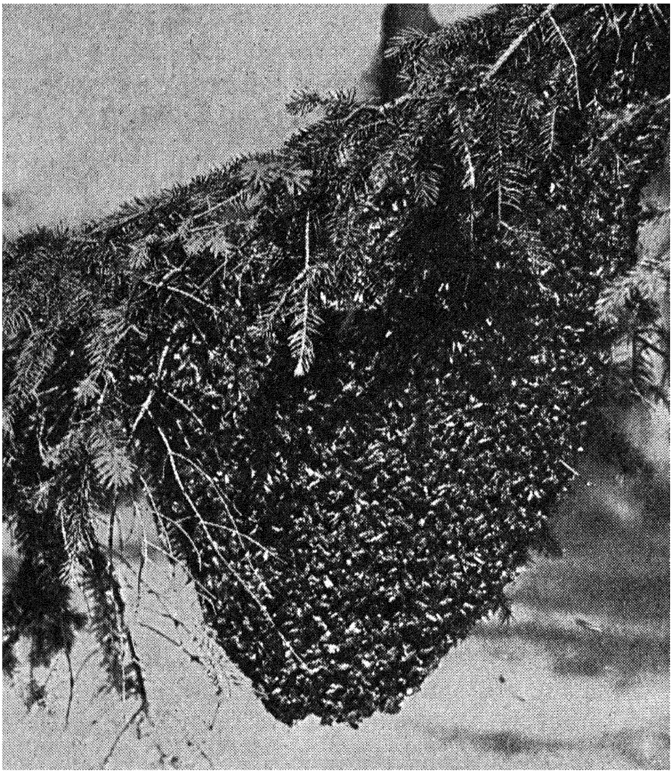
The Workers. The workers are by far the most numerous inhabitants of the hive; they are undeveloped females, smaller than drones, with the ovipositor modified into the sting, and with all the adaptations of legs, wings, and mouth parts, which have been described. Workers may number from 10,000 to 100,000 in a swarm.

With the exception of the process of reproduction, all the varied industries and products of the hive are their business. They perform, at different times, many different kinds of work as well as providing the three hive products—wax, honey, and propolis. In summer they literally work themselves to death in three to four weeks but may live five to six months over winter.

Products of the Hive. *Wax* is a secretion from the abdominal segments of workers, which comes after they have first gorged themselves with honey, and then have suspended themselves by the feet in a sort of curtain. As the wax is produced, it is removed by other workers, chewed to make it soft, and then carried to still others by whom it is built into comb.

This comb is a very wonderful structure, composed of six-sided cells in two layers, so arranged as to leave no waste space, and afford the greatest storage capacity with the use of the least material. Not only is it used for storage of honey, and "bee bread" (a food substance made from pollen and saliva) but also for the rearing of young bees. The eggs are placed, one in a cell, by the queen and sealed up by the workers, making what is called "brood comb."

Honey is made from the nectar of flowers which is taken into the crop of the bee, its cane sugar changed to the more easily digested grape sugar, and then emptied into the comb cells,



Courtesy of Nature Magazine.

FIG. 88. A swarm of bees, estimated at about 75,000 in this mass. With their queen they have left the hive and have "swarmed" on the branch. Soon they will leave for a new home or the bee-keeper may put them in a hive where they will start a new colony.

where it is left to ripen and evaporate before being sealed up. Until the seventeenth century, people did not know how to make sugar, and depended largely upon honey for this necessary

food. At present the bee products in United States are worth $22,000,000 per year.

The removal of honey by man does not harm the bees if about thirty pounds be left for their winter use, that being sufficient to feed the average colony of about 40,000 bees for an ordinary winter.

Propolis, or bee glue, is another important product of the hive. It is gathered from the sticky leaf buds of some plants. Bees will even use fresh varnish if they can get at it. It is used to make smooth the interior of the hive, to help attach the comb, to close up holes and cracks, and even to varnish the comb if it is left unused for a time; it is the brown substance which may be seen on honey boxes in the stores.

Industries of the Colony. Not only do the workers prepare the wax, honey, and propolis, as needed, but they have other duties as well, which they take turns in performing. Some attend and feed the queen or drones; some act as nurses to the hungry larvæ, which they feed with partly digested food from their own stomachs; some clean the hive of dead bees or foreign matter; some fan with their wings to ventilate the hive and, all the time, thousands of others are bringing in the nectar, pollen, and propolis as needed for use of the colony. Such a communal or colony life illustrates the highest development of division of labor found among the animals lower than man. It occurs among some ants and wasps as well as bees, though nowhere carried to a higher point than in the honey bee.

Larval Forms of Insects. The larval forms of many insects are so different from the adults that they have received separate names which sometimes confuse the relationship.

	beetle		grub
	fly		maggot
The larva of the	bee	is called a	grub
	mosquito		wiggler
	butterfly		caterpillar or "worm"
	moth		caterpillar or "worm"

We speak of "silk worms," or "apple worms," etc., when we really refer to larval forms of moths; "cabbage worms" are larvæ of butterflies.

"Wire worms" are beetle larvæ; the "moth" that eats woolens is the larva and not the moth itself; the "carpet bug" or "buffalo bug" is the larva of a beetle.

COLLATERAL READING

Manual for the Study of Insects, Comstock, pp. 48–76, 104–118; *Insect Life*, Comstock, pp. 11–21; *Guide for the Study of Insects*, Packard; *Entomology for Beginners*, Packard, pp. 178–223; *Insecta*, Hyatt and Arms; *Elements of Zoölogy*, Davenport, pp. 11–89; *Animals and Man*, Kellogg, Chap. XV; *Textbook of Zoölogy*, Colton, pp. 1–53; *Lessons in Zoölogy*, Needham, pp. 36–104; *Practical Zoölogy*, Davidson, pp. 30–125; *Comparative Zoölogy*, Kingsley, pp. 213–234; *Elementary Zoölogy*, Galloway, pp. 232–273; *First Book of Zoölogy*, Morse, pp. 49–108; *General Zoölogy*, Linville and Kelly, pp. 1–100; *General Zoölogy*, Herrick, pp. 153–195; *Animal Life*, Jordan, Kellogg and Heath, pp. 149–155; *Animal Studies*, Jordan, Kellogg and Heath, pp. 130–149; *Introduction to Biology*, Bigelow, pp. 279–286; *Applied Biology*, Bigelow, pp. 380–398; *Nature Study and Life*, Hodge, Chaps. V, X, pp. 181–294; *Handbook of Nature Study*, Comstock, pp. 308–451; *Life in Ponds and Streams*, Furneaux, pp. 202–345; *Life and Her Children*, Buckley, pp. 201–268; *Insect Friends and Foes*, Craigin, pp. 53–76; *Insect Life of Farm and Garden*, Sanderson, see index; *Insects Injurious to Fruits*, Saunders, see index; *Injurious and Useful Insects*, Miall, see index; *Insects and Insecticides*, Weed, see index; *Insects Injurious to Vegetation*, Chittenden, see index; *Insect Pests of Farm and Garden*, see index; *Insects Injurious to Trees*, N. Y. State Report; *Economic Entomology*, Smith, pp. 11–51, 79–100; *Economic Zoölogy*, Osborne, pp. 235–310; *Economic Zoölogy*, Kellogg and Doane, pp. 14–25, 125–182; *Life Histories of American Insects*, Weed, see index; *Insect Book*, Howard, pp. 332–346; *Butterfly Book*, Holland; *Moth Book*, Holland; *How to Know the Butterflies*, Comstock; *Cornell Leaflets* (bound volume), 1894–1904, pp. 135–140; *Cornell Leaflets*, pp. 226–261; *Cornell Leaflets*, pp. 529–557; *Cornell Leaflets*, pp. 213–223; *Cornell Leaflets*, 1915, pp. 153–190; *Cornell Leaflets*, 1916, pp. 122–152.

SUMMARY OF CHAPTER XXIV

LEPIDOPTERA (SCALE WINGED) (MOTHS AND BUTTERFLIES)

1. Structure.

- a. Head.
  - (1) Antennæ knobbed or feather-shaped.
  - (2) Compound eyes.
  - (3) Mouth parts (adapted for sucking nectar).
    - (a) Labrum and mandibles reduced.
    - (b) Maxillæ form proboscis.
    - (c) Labium reduced to palpi.
- b. Thorax.
  - (1) Legs small and weak.

(2) Wings.
(a) Large.
(b) Few veins.
(c) Scaled.
(d) Slow motion.
c. Abdomen.
(1) Little specialized.

2. Life history (complete metamorphosis).
a. Egg laid on food plants.
b. Larva, caterpillar (eating stage, harmful).
c. Pupa or chrysalis (quiet stages, silk).
d. Adult moth or butterfly (reproductive stage, pollination).

HYMENOPTERA (MEMBRANE WINGED) (BEES, ANTS, AND WASPS)

1. Structure.
a. Head.
(1) Antennæ short and elbowed.
(2) Eyes very large.
(3) Mouth parts (adapted for biting, lapping, and sucking).
(a) Labrum small and triangular.
(b) Mandibles sharp (for biting).
(c) Maxillæ long and sharp (for cutting wax, etc.).
(d) Labium tongue-like (for lapping nectar).
b. Thorax.
(1) Large and strong.
(2) Wings small, but powerful.
(3) Legs.
(a) Anterior with antenna cleaner.
(b) Middle with pollen spine.
(c) Posterior with pollen basket and wax shears.
c. Abdomen.
(1) Six segments.
(2) Ovipositor or sting.
(3) Wax glands.

2. Life history (complete metamorphosis) (communal life).
a. Egg (laid by queen in comb cells).
b. Larva (helpless grub, fed by workers).
c. Pupa (sealed in wax cell).
d. Adult, three forms.
(1) Queen.
(a) Large, fertile female.
(b) Produces eggs.
(2) Drone.
(a) Thick body.
(b) Large eyes.
(c) Fertilizes eggs.

(3) Workers.
  (a) Smaller.
  (b) Sting in place of ovipositor.

3. Hive products.

a. Wax (secreted from abdominal segments of workers).
b. Honey (concentrated and partly digested nectar).
c. Propolis, "bee bread" (glue made from plant gums).

4. Division of labor (among workers).

a. Collection of nectar, pollen, and gum.
b. Preparation of wax, honey, propolis, and bee bread.
c. Feeding queen, drones, and larvæ.
d. Ventilating hives by fanning; cleaning hives.
e. Guarding hives from intruding insects and robber bees.

CHAPTER XXV

INSECTS AND DISEASE

Vocabulary

Excrement, waste matter thrown off by animals from the intestines or kidneys.
Coöperation, working together for a single purpose.
Contract, to "take" a disease.

Flies and Mosquitoes

Another insect order which we shall take up very briefly is the *diptera* (two-winged) which includes the flies and mosquitoes. They are studied chiefly because of their relation to the carrying of disease germs. The diptera differ from all other insects by having but one pair of wings, the posterior pair being replaced by flat or knob-shaped balancers. The mouth parts are fitted for piercing, rasping, and sucking, and the metamorphosis is complete.

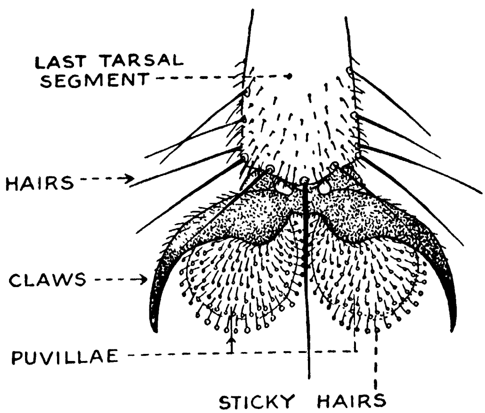


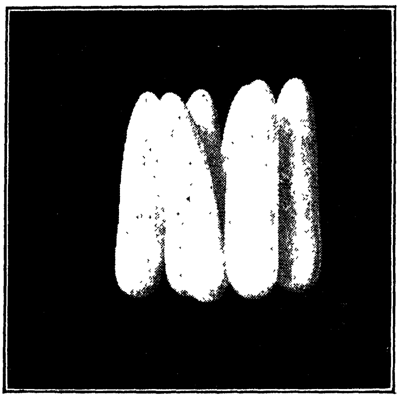
Fig. 89. The foot of the house fly, showing claws and sticky hairs which help in carrying germs.

The Typhoid Fly. The common house fly (typhoid fly) has very highly developed mouth parts adapted for rasping and sucking, large eyes, and short fleshy antennæ. Its wings, though but two in number, are well developed, and operated at high speed by the powerful muscles of the thorax; instead of the posterior pair there are a pair of

flattened balancers. The six legs are well developed and the feet (tarsi) are provided with claws and sticky hairs which aid in locomotion. Unless these hair tips are very free from dust they will not stick well and the fly cannot walk readily on smooth surfaces, hence the care with which it cleans its feet by constantly rubbing them against each other and its body.

Life History. Our principal concern is with the life history and habits of the fly rather than with its structure, since it is in this connection that it affects man's health.

The *eggs* are deposited in horse manure if it is to be found, or in other similar matter, from one to two hundred being laid by each female. They hatch in one day into the *larval* form which we call maggots, and in this stage do some good as scavengers. After eating and growing for five or six days, the larvæ pass into the *pupal* condition, inside the last larval skin, which thus takes the place of a cocoon. From this the adults emerge in about a week. The whole development from egg to adult takes about two weeks. Breeding begins early in spring, and continues till cold weather. Supposing that half the eggs produced females and these reproduce at the same rate, calculate the number of flies that might be produced by one adult which had survived the winter, and the enormous number of flies in existence will be accounted for.

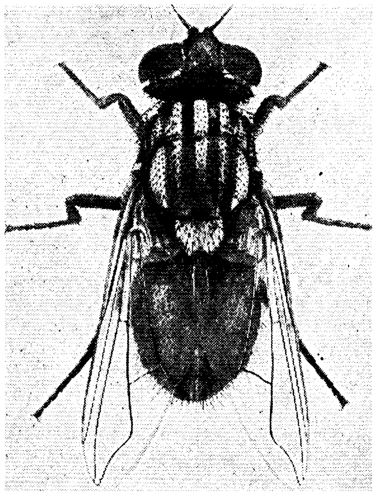


American Museum of Natural History.

FIG. 90. Eggs of the house fly, greatly magnified.

Danger from Flies. Flies have always been regarded as more or less of a nuisance, as they crawl over our food and our bodies, fall into milk and other liquids, and annoy mankind in various ways, but their real harm has only recently been realized.

They live in and feed upon manure and filth, then come and crawl over our food and faces, or wash themselves in the cream pitcher. When we realize that typhoid, cholera, and dysentery are intestinal diseases, that the germs are carried off by the excrement in which flies thrive, it is no wonder that they infect our food when they crawl upon and share it with us. The fly is not only a filthy but a very harmful insect and one to be avoided and destroyed.



Courtesy of the American Museum of Natural History

FIG. 91. Common house (typhoid) fly.

A fly eats its own weight of food every day. Its food is largely manure, sputum, and other filth, though it also samples our food at table. Disease germs may pass through the fly's intestine unharmed and remain active in the familiar "fly specks" which are deposited at intervals of five minutes. Thus the fly carries filth and disease both externally on its feet and body and internally by way of its food and excreta.

Our common flies transmit typhoid, cholera, summer complaint, dysentery, tuberculosis, and probably other diseases where the germs pass from the body in any form of excrement, pus, or sputum. The tsetse fly of Africa transmits the deadly "sleeping sickness." Thus it is seen that flies which we formerly regarded as an unavoidable nuisance, have been proven to be responsible for the death of more people than all wild beasts and reptiles together, and that actually they are more dangerous to man than the tiger, grizzly, or rattlesnake.

Rate of Reproduction. In the face of its enormous rate of increase, "swatting" of individual flies is a losing battle as the

following figures show. Supposing that reproduction was unchecked and that all offspring survive (which fortunately is not always the case) then one fly would produce in the different generations of two weeks each as follows.

From Kellogg and Doane.

FIG. 92. Larvæ and pupæ of house fly, in manure. Natural size. Larvæ are white; pupæ dark, shorter, and thicker.

1st		200	(half females)
2nd	(100 × 200)	20,000	(" ")
3d	(10,000 × 200)	2,000,000	
4th		200,000,000	
5th		20,000,000,000	
6th		2,000,000,000,000	
		2,020,202,020,200	total in 12 weeks

or the perfectly unthinkable number of over two million millions in half the breeding season. This would be over 20,000 flies to

be killed by each man, woman, or child in the United States—and this the progeny of one adult female which survived the winter.

Fly Control. The only time that "swatting" flies does much good is early in the spring when it is possible to kill the females

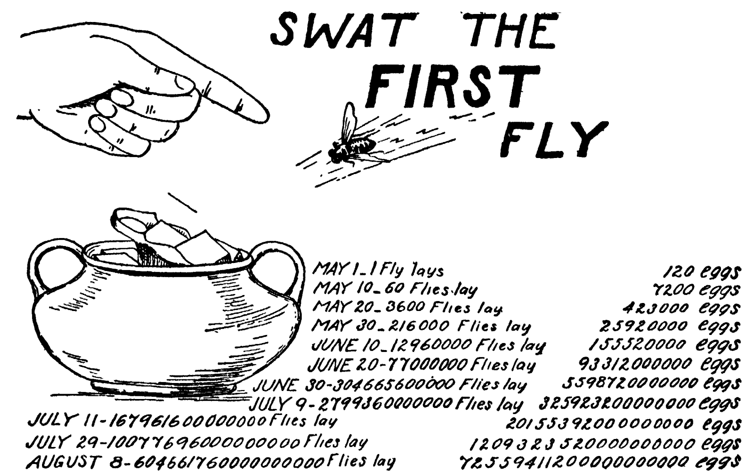


FIG. 93. Cartoon from newspaper showing rate of increase of the fly.

that have survived the winter, and thus prevent their breeding, before the number is too great for this method to be effective.

Fortunately there are more efficient ways of destroying this dangerous pest. These are briefly tabulated below; government bulletins fully describing all methods may be had for the asking, and general coöperation has much reduced the pest in many cities. The following are the most efficient methods of control:

1. Horse manure and other filth can be removed, screened, or chemically treated to kill the larvæ.
2. Garbage and sewage can be properly covered and removed.

3. Houses can be screened.
4. Food, especially in stores, can be protected.
5. Fly traps and wholesale poisons are helpful.

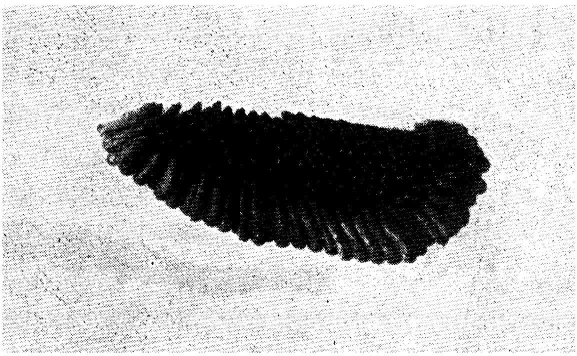
The Mosquito. The mosquito is another member of the diptera which demands mention because it, too, transmits serious diseases to man though it acts in a different way from the typhoid fly. The germs actually develop a part of their life history within the mosquito's body, while the fly merely carries its dangerous burden, mechanically.

Mouth Parts. In the mosquito, the labrum, tongue, mandibles, and maxillæ are reduced to sharp, lance-like bristles, enclosed within the labium as a sheath, and are adapted for piercing and sucking. In order to dilute the blood, so that they can withdraw it, they inject a little saliva, which causes the usual irritation and swelling of a mosquito bite.

Disease Transmission. This would be bad enough, but it has been absolutely proven that if certain species of mosquitoes bite a person having either malaria or yellow fever, the protozoan which causes the disease, is taken up with the blood, develops in the mosquito's body and may be injected with the saliva into the blood of a well person. Not only has this been shown, but by means of experiments in which several men sacrificed their lives, it is also proven that this is the *only* way in which these, and probably other diseases, are transmitted. Men tended yellow fever patients, slept in their beds, wore their clothes and though exposed in every way, did not contract the disease as long as screened from mosquitoes. Others who allowed themselves to be bitten by mosquitoes which had previously bitten yellow fever patients, invariably contracted the disease, which in some cases resulted in their death. From these sacrifices, methods of control have developed which have saved thousands of lives in all parts of the world.

Life History. As with the fly, a knowledge of its life history enables man to contend with the mosquito, and these campaigns are much more successful than those against the fly. The eggs are laid in stagnant water; ponds, rain barrels,

and even tin cans furnish ideal breeding places. They are deposited in tiny rafts, consisting of many eggs covered with a waterproof coating, and when they hatch the larvæ emerge downwards into the water, and become the familiar "wigglers" seen in rain barrels. Though living in water the mosquito larva breathes air, which it obtains through a tube, projecting from the posterior of its abdomen. It may often be seen with this tube at the surface and the body hanging head downwards



From Doane.

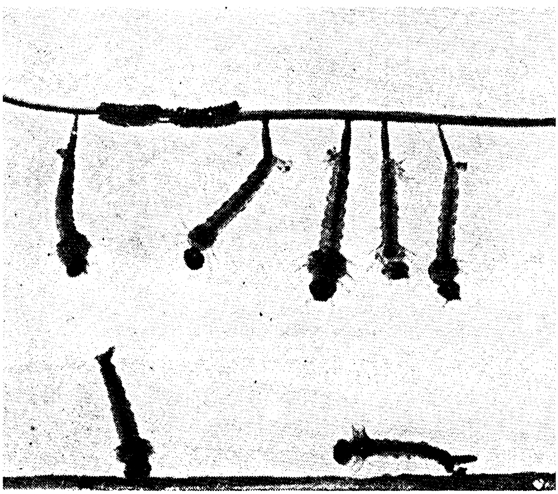
FIG. 94. Mass of mosquito eggs as they float in masses. Greatly magnified.

in the water. The pupa stage is also passed in the water and differs from most insect pupæ in being an active "wiggler" as well as the larva. It differs from this larva in having a large head provided with two air tubes for breathing. The adult emerges from the floating pupa skin and is easily killed by any shower that wets its unexpanded wings, or any spray that may be thrown upon it.

Our commonest northern mosquito (Culex) probably does not transmit disease and may be distinguished from Anopheles which carries malaria, by the fact that the latter stands almost on its head when at rest, while Culex holds its body more nearly horizontal. Fortunately, Aedes, which transmits yellow fever, is a tropical species of mosquito and does not usually invade the temperate regions.

Mosquito Control. This outline of the metamorphosis gives the key to the methods of attack which consist of:

1. Drainage of swamps, covering or removal of rain barrels, cisterns, cans, or any hollows where water may accumulate.
2. Spraying swamps and ponds with petroleum which covers the water with a film of oil so that neither larva nor



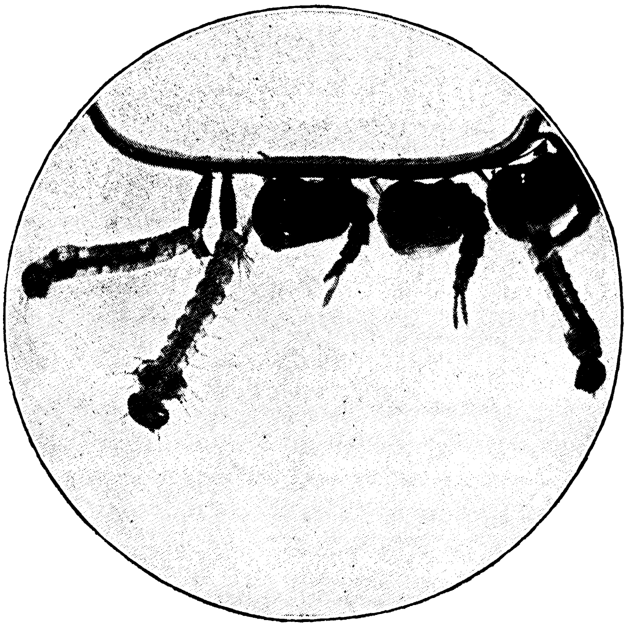
From Doane.

Fig. 95. Mosquito eggs and larvæ; two larvæ feeding on bottom, others at surface to breathe. Note the two egg masses and the breathing tubes touching the water surface.

pupa can breathe. This also kills any adults which it strikes. Oil treatment is injurious to plants and fishes in the water thus treated.
3. Fish and dragon flies are natural enemies of mosquitoes and should be encouraged.
4. Careful screening of houses and wearing of protective clothing especially in infected regions is a helpful precaution.

5. Persons suffering from malaria should avoid being bitten lest they thus infect others. Yellow fever cases are now quarantined in screened rooms for the same reason.

By such methods both malaria and yellow fever have been stamped out in many regions formerly very dangerous. The



From Doane.

FIG. 96. Mosquito larvæ and pupæ, with their breathing-tubes at the surface of the water.

chief obstacle to the completion of the Panama Canal by the French was the awful death rate due to these diseases. Now, with proper sanitary measures, the canal zone has a lower death rate than New York City. Because of the modern knowledge of disease transmission and control as applied by Colonel W. C. Gorgas, the completed canal stands as a monument to American health science as well as to American engineering. The consequences of heroic experiment

have been far reaching in other notable plague spots. Central America, West Indies, and the Philippines are now healthful regions. New Orleans, formerly scourged by epidemics of yellow fever, is now almost free from this dreadful malady.

A Biologic Victory. One of the most brilliant chapters in the history of the war against disease recounts the work of four American Army Surgeons in the conquest of yellow fever.

In 1900, Doctors Reed, Carrol, Lazear, and Agramonte were sent to Cuba to study this disease which had always been a scourge in the West Indian region and was now spreading among our soldiers. They suspected a certain kind of mosquito as the carrier, but could not test their theory on animals, as only human beings have yellow fever. So they decided to try it on themselves, and allowed mosquitoes, which had bitten yellow fever patients, to bite them and infect them with the deadly germs. Carrol was the first to be ill, but after a long and painful sickness, finally recovered. Lazear was the next to come down with the disease and he died. Still the experiments went on, despite the terrible risk, and there were many new volunteers. Two others were selected, a soldier, Kissinger, and a civilian, Moran. Both insisted that they receive no pay, as they willingly offered their lives for the benefit of humanity. Both men recovered after severe illness, but Kissinger was permanently disabled as the result of his heroism.

Based on the work of this gallant band of soldiers of science, they were able to prove that the mosquito was the *only* carrier of yellow fever, and to propose means for its control. An active campaign was begun at once and in 1901 only eighteen deaths occurred in Havana and none at all in 1902. The terrible curse of the tropics was wiped out.

Major Reed writes "In my opinion this exhibition of moral courage has never been surpassed in the Army of the United States."

The history of medicine and sanitation is full of such examples of quiet heroism, where men have offered themselves to suffering and death far worse than is incurred in battle and without the excitement of war or the encouragement of popular applause.

The conquest of malaria was brought about in similar manner, by the careful research and courageous experiment of English and Italian doctors. As late as 1894 the Standard Dictionary of Medicine said that malaria was caused by "an earth-born poison generated in the soil" and, as its name signifies, was associated with bad air especially night air.

The malaria germ had been seen by a French surgeon in 1880, but not associated with mosquitoes at all, though in 1884 an American, A. F. A. King, had urged this as possible. In 1897 two English physicians, Manson and Ross, traced the germ of bird malaria to the mosquito and the following year two Italians, Grassi and Bignami, found the germ of human malaria in the body of mosquitoes.

By experiments similar to those described for yellow fever, it was proven possible to live in health in the worst swamps of the Roman Campagna, if protected from mosquitoes. To finally prove their action in malaria transmission, Doctor Manson's son and another volunteer were inoculated with malaria by mosquitoes brought from Italy. Both took the disease, but fortunately were cured. It is to such work as this that science owes her victories and to it we owe also our greater safety from disease.

Life History of the Malaria Parasite. The malaria parasite is a protozoan; it passes through two distinct stages in its life history: the sexual stage, which occurs in the body of the mosquito, and the asexual stage, which is passed in the body of man and which causes malaria. The following description and the drawing which accompanies it, are the work of Miss Ellen Edmonson of Cornell University.

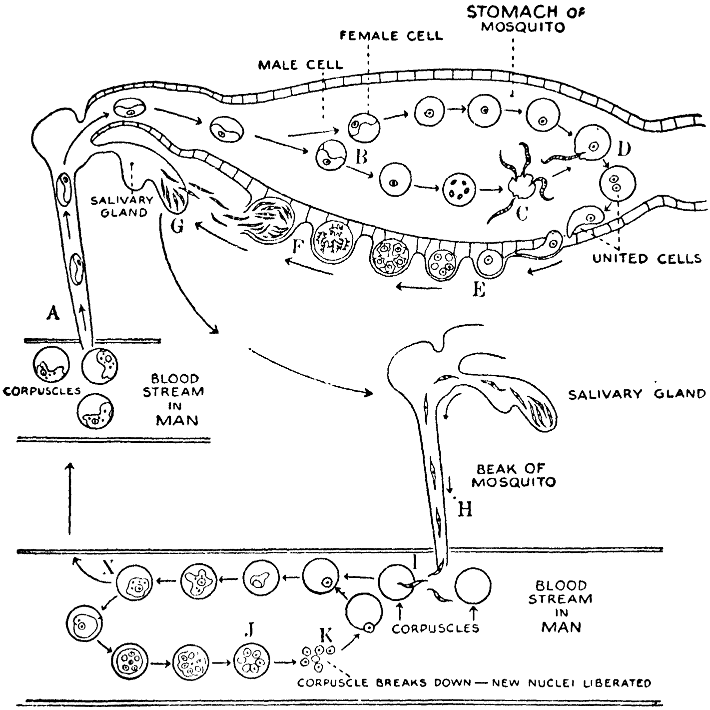


FIG. 97. The life history of the malaria germ. (A protozoan.) A. Mosquito takes up infected blood corpuscles from man. B. Germs of both sexes develop in the stomach of mosquito. C. Mature male cells unite with mature female cells (D). E. Fertilized cell forms a cyst on outer wall of stomach. F. Cyst cell produces many slender nuclei. G. These nuclei reach the salivary glands of mosquito. This part of the development takes twelve days. H. Infected mosquito bites man and injects germs along with saliva. I. The germs enter and live in the human blood corpuscles (X). J. They develop many nuclei in each corpuscle. K. These nuclei are discharged and enter other corpuscles. The period of malarial "chill" is after the nuclei are set free;—then follows the period of "fever." X. Corpuscles at this stage may be taken up by a mosquito, and go through the stages A to G. In this way more mosquitoes are infected and the disease is spread.

Sexual Development in Mosquito. From the blood stream of a person infected with malaria the mosquito takes up through its beak blood corpuscles which contain the malarial germ (A). Some of these are male, some female. They pass into the stomach of the mosquito where the female and the male cells develop differently (B).

The nucleus of the male cell divides, forming new nuclei which develop into flagellate forms. When these are mature, the corpuscle breaks down and the male flagellate forms are set free (C). These unite with the mature female cell (D).

The fertilized cell passes through the stomach wall and forms a cyst or tubercle on the outer wall of the stomach (E). It divides into daughter nuclei, each of which produces many new nuclei, elongated forms (F). When these are mature the cyst breaks, and they pass into the body cavity of the mosquito. They find their way to the salivary glands of the mosquito (G).

Twelve days are required for the development from the time the cells enter the stomach till they become the salivary gland form.

Asexual Development in Man. When the mosquito, having the malaria germs in its salivary glands, bites man, the germs with the saliva are introduced into the blood stream (H). These enter the red blood corpuscles (I). They live in the blood corpuscles and deposit toxic black and reddish granules.

If they remain in man they grow and divide into daughter nuclei (J). When these are mature the corpuscle breaks down and the nuclei are liberated (K). These enter other blood corpuscles and the cycle continues. It is after the nuclei are set free that the "chills" characteristic of malaria are felt, followed by fever.

Stage (X) may be taken up by a mosquito where it goes through the sexual form of development.

SOME MEANS OF GERM TRANSMISSION

Disease	Transmitted by	Means of prevention
Malaria	Mosquito	Drainage and oiling of swamps Screening and isolation of patients
Yellow fever	Mosquito	As above
Typhoid fever	Flies	Destroy breeding places Kill breeding females in spring Screen food and waste
Tuberculosis	Flies	As above
Dysentery	Flies	
Relapsing fevers	Lice Bedbugs	Cleanliness, destruction of pests
Sleeping sickness	Tsetse fly	Protection against fly attack
The "Plague"	Fleas on rats and squirrels	Destruction of rodent hosts

COLLATERAL READING

Principles of Health Control, Walters, pp. 347–369; *Economic Zoölogy*, Kellogg and Doane, pp. 349–385; *General Zoölogy*, Linville and Kelly, pp. 284–287; *Town and City*, Jewett, pp. 228–241; *Primer of Sanitation*, Ritchie, pp. 145–150, 103–116; *Applied Biology*, Bigelow, pp. 282–286; *Mosquitoes or Man*, Boyce, pp. 204–210; *Protozoölogy*, Calkins, pp. 279–285; *The House Fly*, Howard, entire; *Sanitation Practically Applied*, Wood, pp. 420–444; *Community Hygiene*, Hutchinson, pp. 220–232; *Scientific Features of Modern Medicine*, Lee, pp. 79–85; *Rural School Leaflet* (Cornell), Vol. IX, pp. 184–186; *Bulletin No.* 74, *Mississippi Exp. Station*, entire; *Numerous other Government Bulletins; Biology of Man and Other Organisms*, Linville, pp. 36–71; *Practical Zoölogy*, Hegner, pp. 73–101; *Insects and Disease*, Doane, entire.

See also references in encyclopedia or any textbook index on,

Flies	Typhoid fever
Mosquitoes	Malaria
Fleas	Yellow fever
Protozoa	Bubonic plague
Etc., etc.	

SUMMARY OF CHAPTER XXV

INSECTS AND DISEASE

1. Reason for study of Diptera.

2. Characteristics.

- a. One pair of wings.
- b. Balancers
- c. Complete metamorphosis.
- d. Mouth parts for rasping and sucking (fly).
- e. Mouth parts for piercing and sucking (mosquito).

3. The fly.

- a. Life history.
  - (1) Egg.
    - (a) Laid in manure or filth.
    - (b) 200.
    - (c) Hatch in one day.
  - (2) Larva (maggot).
    - (a) Scavengers.
    - (b) Period, 5–6 days.
  - (3) Pupa.
    - (a) Passed in last larva skin.
    - (b) Period, 7 days.
  - (4) Adult.
    - (a) Develop in two weeks all summer (compute numbers).

b. Harm done by flies.
  (1) Annoyance to people and animals.
  (2) Transfer filth to food.
  (3) Transfer germs externally and internally
    (a) Typhoid.
    (b) Cholera.
    (c) Dysentery.
    (d) Tuberculosis.
    (e) Sleeping sickness.

c. Methods of control or prevention.
  (1) Cover manure.
  (2) Cover foods.
  (3) Remove garbage.
  (4) Use traps.
  (5) Use screens.
  (6) "Swat 'em."

4. The mosquito.

a. Life history.
  (1) Egg.
    (a) In rafts on the water.
  (2) Larva (wigglers).
    (a) Breathe head downwards.
  (3) Pupa.
    (a) Also active.
    (b) Breathe head upwards.
  (4) Adult.
    (a) Female bites animals.
    (b) Male harmless.

b. Control and prevention.
  (1) Drainage of swamps.
  (2) Fish and dragon flies.
  (3) Spraying with oil.
  (4) Screening houses.
  (5) Protecting those who are sick.

c. Kinds.
  (1) Culex (common northern mosquito).
    (a) Body horizontal.
  (2) Anopheles (malaria).
    (a) Body almost vertical.
  (3) Aedes (yellow fever).
    (a) Tropical.

d. Relation to disease.
  (1) Yellow fever.
  (2) Malaria.
  (3) Heroic experimenters.

CHAPTER XXVI

INTRODUCTION TO THE VERTEBRATES

Vocabulary

Specialization, development of parts for special function.
Survival, remaining alive.
Ultimate, furthest.
Vertebrates, animals having a backbone composed of vertebræ.

While it is certain that all living things are more or less related to each other, still they have developed along very different lines, and to very different extents.

Among animals, the *protozoa* seem to have carried the specialization of the *single cell* about to its limit, which, while assuring their survival, could not possibly raise them very high in the scale of development.

The *sponges* have obtained the utmost possible advantage from colonizing slightly specialized cells in slightly specialized bodies, and have attained a considerable advance over the protozoa.

The *hydra* and its relations reached a much higher plane by development of *tissues* for special purposes.

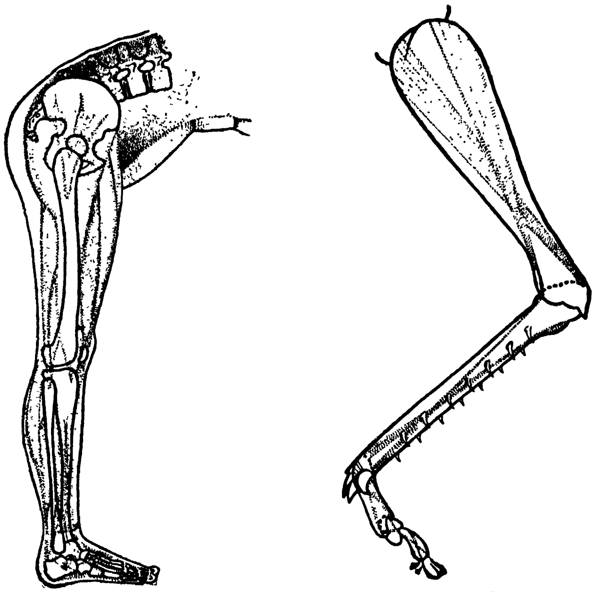
The *worms* mark a very diverse class but some of them have well-developed systems of *organs,* digestive, circulatory, nervous, etc., which had never appeared in previous forms.

Diverging from the worm type it seems as if nature had tried out several schemes of development, carrying each to a point where it could no longer be much improved.

The *molluscs* represent the ultimate advantage to be gained from a protective shell and rather high internal development, coupled, in most cases, with an inactive life. This made for safety first, but limited increase in activity and intelligence.

The *arthropods,* especially the insect class, tried what could be done with an external protective skeleton, but one pro-

vided with joints, so that activity need not be sacrificed to safety. This has produced the winners in life's race, if numbers be the standard. But the external skeleton and the ventral nervous system imposed obstacles to large increase in size, on the one hand, and to a highly developed brain, on the other.



From Pearse.

FIG. 98. Diagram showing typical arrangement of skeleton and muscles in a vertebrate (man), and an invertebrate (grasshopper). The vertebrate has an internal skeleton with the muscles on the outside. The invertebrate skeleton, if present, is external and the muscles are placed within it.

A third line of development, with the internal skeleton and the nervous system dorsal in the body, was attempted by the group of animals called the vertebrates. This permitted great increase in size both of body and brain, but gave less protection. This very fact necessitated an active and intelligent life to oppose or escape their enemies. The vertebrates thus have come to be the highest in the scale of animal development and include the following classes:

1. The Pisces (fishes).
2. The Amphibia (frogs, toads, salamanders).
3. The Reptilia (snakes, turtles, lizards).
4. The Aves (birds).
5. The Mammals (rat, cattle, cat, man).

The vetebrates include many very different animals, but they all agree in the following points in which they also differ from all the other forms studied. These other forms are sometimes all classed together as the invertebrates.

All vertebrates have:

1. An internal skeleton of bone or cartilage.
2. A spinal column composed of vertebræ.
3. A dorsal nervous system.
4. Two body cavities: a dorsal one for the nervous system and a ventral one for the other organs.
5. Eyes, ears, and nostrils always on the head.
6. Jaws, not modified limbs; move up and down.
7. Eyelids and separate teeth are usually present.
8. The heart is ventral and blood is red.
9. Never more than two pairs of limbs.

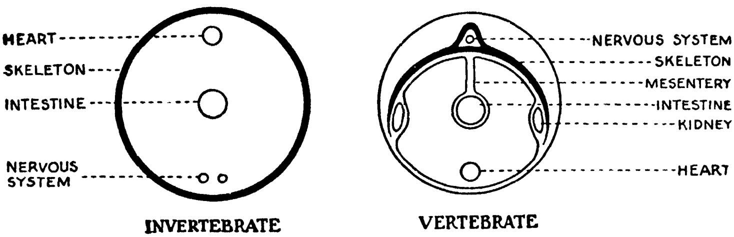


FIG. 99. Diagrammatic cross sections showing different location of similar organs in invertebrate and vertebrate animals.

The human body is a true vertebrate type as we can see by comparing its structure with the above points and we only hold our place in the race of life by our superior brain development. There is not one of the lower groups but has members which excel us in some other respects.

Compare our swimming with the fish, our flight with the bird, or our speed with the deer and it will be seen that we are in-

ferior in many respects to the different members of the animal kingdom. It is the development of our brain that has enabled us to retain the lead in the race of life. Superior intelligence compensates many times over for various physical disadvantages.

Here, as everywhere in Nature, we can see increase in complexity permitting greater division of labor, and this in turn resulting in better adaptation and more perfect performance of function.

If we compare the protozoan to the man on the desert island, then the sponge would represent a condition where there were enough men (cells), so that one could do one thing and one, another. It would be like a small village where one man could make all the shoes, or do all the baking.

In the hydra we find groups of similar cells (tissues) performing a single function. This would correspond to the case where the town had grown large enough so that many shoemakers or bakers were required and each group worked together, as in a factory.

Worms and higher forms, with their tissues grouped into organs, would correspond to larger cities where many kinds of factories were required to carry on the business of the still larger group of people.

COLLATERAL READING

Applied Biology, Bigelow, pp. 417–419; *Animal Studies*, Jordan, Kellogg and Heath, pp. 161–169; *Economic Zoölogy*, Kellogg and Doane, pp. 237–240; *Winners in Life's Race*, Buckley, pp. 1–19; *Animal Life*, Thompson, pp. 248–272; *Comparative Zoölogy*, Kingsley, pp. 127–156; *Zoölogy*, Shipley and MacBride, p. 306; *Elementary Zoölogy*, Davenport, pp. 289–297; *Elementary Zoölogy*, Galloway, pp. 274–280.

SUMMARY OF CHAPTER XXVI
THE VERTEBRATES

1. Development of the branches of the Animal Kingdom.

Branch	Examples (in notes)	Line of development.
Protozoa		Specialized *single cells.*
Sponges		*Groups* of slightly specialized cells. Larger size, colonial habit.
Hydra		Two-layered body wall, *tissues.*
Worms		Systems of *organs,* sense organs.
Molluscs		Protection, inactive, low intelligence.
Arthropods		Jointed exo-skeleton, active. High developed senses and *instinct.* Size and brain development limited.
Vertebrates		Internal skeleton Better developed *brain.* Less protected but more intelligent.

2. Vertebrates.

a. Classes.
- (1) Pisces (fishes).
- (2) Amphibia (frogs, toads, salamanders).
- (3) Reptilia (snakes, turtles, lizards).
- (4) Aves (birds).
- (5) Mammals (rat, cow, cat, man).

b. Characteristics.
- (1) Spinal column.
- (2) Internal skeleton.
- (3) Dorsal nervous system.
- (4) Two body cavities.
- (5) Two pairs of limbs, or fewer.
- (6) Sense organs on head.
- (7) Jaws not developed from limbs.
- (8) Eyelids.
- (9) Separate teeth.
- (10) Ventral heart.
- (11) Red blood.

CHAPTER XXVII

FISHES

Vocabulary

Aquatic, pertaining to the water.
Cartilaginous, made of cartilage, a gristle-like tissue.
Nasal, pertaining to the nose.
Operculum, the covering over the gills in fishes.
Filaments, any thread-like organs.
Prehension, the function of grasping.
Visceral, pertaining to the viscera or abdominal organs.
Pectoral, pertaining to chest or shoulders.
Pelvic, pertaining to the hips.

We call many animals "fish" which are not even remotely related to them, merely because they live in the water. Almost every group of animals has some member classed as "fish" either by name or association.

There is the "jelly-fish" which is related to the hydra and coral. The "star-fish" is an *echinoderm.* "Shell-fish" include molluscs such as clams and oysters. The "cray-fish" is a crustacean and the "silver-fish" is an insect!

Then there is the whale which many consider as a fish, though really it is a mammal, and even the seal is sometimes put in this class, though more nearly related to the cat. The following characteristics distinguish true fish from all other animals.

Fishes are aquatic vertebrates, with either a cartilaginous or bony skeleton; they breathe by means of gills, are usually covered with scales, and have limbs in the form of fins.

External Structure. The body can be divided into three regions, the head, trunk, and tail. There is no narrowing to mark the neck, since the smoother outline is better fitted for passing through the water. The general outline of the body is spindle shaped, flattened more or less at the sides to aid in locomotion by displacing the water as easily as possible.

Scales. The whole body, except the head and fins, is covered with scales overlapping toward the rear, giving protection

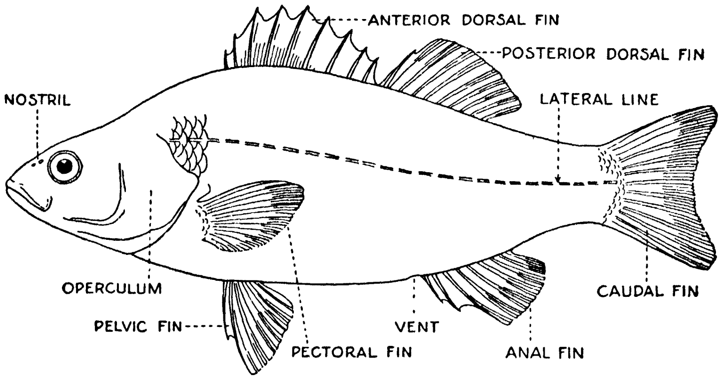


FIG. 100. External structure of the fish. (White Perch.)

The Fins can be divided into those on the median line and those which are paired. The former are probably parts of a continuous fin which, in earlier forms, extended completely around the body, as in the eel or tadpole.

The dorsal fins can be erected and are armed with spines for protection. Smaller spines are also found in the anal and pelvic fins.

The caudal fin is the chief propelling organ and has flexible fin-rays for its support. All the fins in the median line aid in locomotion and steering.

The paired fins are homologous to the limbs of higher animals. The pelvic fins aid in supporting the fish when at rest on the bottom, and both pairs help in balancing and swimming.

The Lateral Line seems to consist of a series of gland-like sacs whose function is thought to be to provide a depth or pressure sense.

The Nostrils have two openings each, so that water can flow through them as the fish swims, bringing with it the particles which cause the sensation of smell. They do not connect with the throat and have nothing to do with breathing, as is the case of air breathers.

The Scales are arranged overlapping to the rear, to give all possible protection, and at the same time permit perfect freedom of motion, and offer no resistance to the water. A slippery secretion aids in locomotion and escape from enemies. Often their color is of advantage in escaping observation, either by enemies or prospective prey.

The Operculum is a strong covering which protects the very delicate gills from injury. It has a slight motion, so as to permit the water to pass out underneath it. The free ventral edge extends far forward under the head almost meeting in a narrow throat region, the isthmus.

All the above features are adaptations for aquatic life, and, together with other internal organs, have made the typical fish unusually well suited to its environment.

The general outline of most fish is about like the perch in having the flattened sides and tapering posterior, which make for speed. All fish have the bulk of their body composed of flexible muscle plates which permit powerful and free use of the caudal fin in locomotion.

and at the same time allowing great freedom of motion. They are supplied with a slimy secretion which aids in locomotion and in escape from enemies. In some fish, such as the trout and catfish, the scales are minute or lacking. In most cases the color of the skin corresponds to the fish's surroundings and is therefore a protection.

Head. The head is usually pointed, protected by plates instead of scales, and attached directly to the trunk. The lack of a neck is no disadvantage, as the fish can turn its whole body as quickly as most animals can turn their heads.

The *mouth* is usually at the extreme anterior end since it is the only organ for food-getting or defense, and it is provided with numerous sharp teeth, arranged on three sets of jaw bones and slanting inward so that there is little chance for a victim to escape.

There are two *nasal cavities* each with two nostrils. They are used for smell only, since they do not connect with the throat and cannot be used in breathing.

The *eyes* are large, somewhat movable, and have no lids, but have a cornea, lens, retina, etc., somewhat similar to our own, and are entirely different from the compound eyes of the insects.

The *ears* are embedded in the skull and do not show externally; they probably function as balancing organs and are used to detect vibration, rather than sound, as fish have no sound-making apparatus and probably cannot "hear" in the sense that we do.

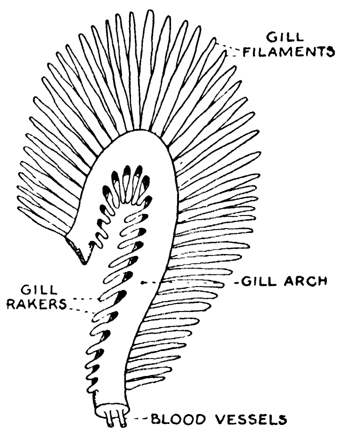


FIG. 101. An entire gill seen from the side. (Enlarged.)

The Gills. At each side of the head is a crescent-shaped slit which marks the rear border of the gill cover or operculum. These slits almost meet on the ventral side, leaving only a

narrow isthmus at the throat region, and thoroughly exposing the gills to the water. If we look inside the mouth we can see that the throat has five slits on each side, leaving four gill arches between them and if the operculum be lifted, the outer sides of these gills can be seen.

Each gill consists of an arch of bone between the slits in the throat wall, to which are attached two rows of thin-walled thread-like appendages called the gill filaments. These filaments are richly provided with capillaries, so that the blood is brought in close contact with the water over a very large surface. This permits the exchange of oxygen (dissolved in water) and carbon dioxide by means of osmosis. The gill arches have finger-like projections called gill rakers, on the side toward the throat, which prevent food or dirt from getting into the filaments and also keep the arches separate to allow free circulation of water.

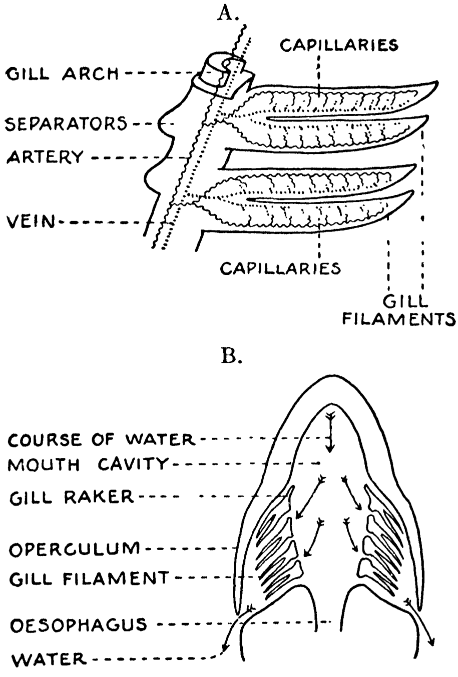


FIG. 102. Gill structure in the fish. A. Gill filaments and arch, greatly enlarged. B. Diagram of mouth, showing location of gills and course of water over them.

The water is taken in at the mouth, which is then closed, forcing it through the gill slits over the filaments and out beneath the operculum; the forward motion of the fish aids in this process.

Here, as in all breathing organs, we find a large extent of

surface, thin membranes, and rich blood supply, all adaptations for osmotic exchange, together with protective devices in the form of operculum and gill rakers, and provision for a free circulation of water.

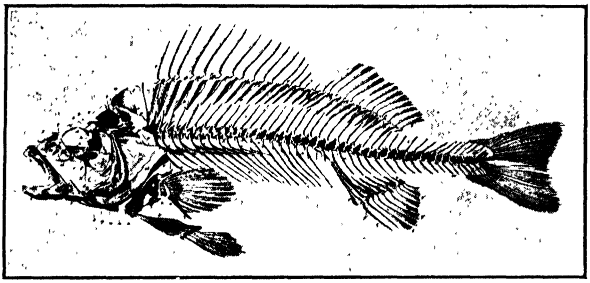
Trunk. Extending along both sides of the body backward from the operculum is a row of pitted scales with sense organs beneath them, known as the lateral line. This probably aids the ears in feeling vibrations, and functions as a pressure organ to estimate the depth at which they swim. The fins are the most characteristic and noticeable appendages of the trunk and consist of a double membrane, supported by cartilaginous or spiny rays, and operated by powerful muscles. Their shape and number vary with the kind of fish, but there are always two pairs, the pectoral (anterior) and pelvic (posterior) fins, which are homologous with the arms and legs of other vertebrates. The other fins are all on the median (middle) line of the trunk, there being sometimes two dorsal fins; always a large tail (caudal) fin, and an anal fin just back of the vent. In general the fins are beautifully fitted for locomotion in the water, but they are differently used in this process, the caudal fin being the chief propelling and steering organ. The paired fins aid in locomotion and in balancing, and also support the body when resting on the bottom. The other median fins aid in steering and are often provided with sharp spines for defense as well.

The bulk of the fish's body consists of powerful muscles arranged in plates. The flexible backbone is made up of very numerous vertebræ, which together permit the fins to be utilized to the fullest extent and provide a system of aquatic locomotion second to none in the world, aided as it is by the pointed, scale-covered, slippery body.

Internal Structure. Digestive System. The food of most fishes consists of other aquatic animals, though a few are vegetarians. It is grasped by the mouth, but the teeth serve only for prehension and not for chewing. On this account the gullet is large and short, and the stomach is provided with powerful digestive fluids. As in most carnivorous animals, the intestine is rather short, making only two loops. Opening into it is the duct

from a well developed liver between whose lobes the gall sac can be found.

Circulation. The fish has a heart consisting of two chambers, an auricle and a ventricle, located just posterior to the isthmus. So it is almost literally true that its "heart is in its throat." The blood leaves the heart by a large artery that branches to



After Cuvier.
Courtesy of the American Museum of Natural History.

FIG. 103. Skeleton of European Perch, illustrating the bony framework of the higher fishes.

The whole fish is adapted for thrusting rapidly forward through the water. The tapering head ends in a sharp prow extending from the nose to the neck. The brain-case is braced on all sides to receive the forward thrust of the many-jointed backbone, which is driven forward by the tail. The fins are spread upon bony sticks or rays, which are supported by bony pieces that are embedded in the flesh. Between the supporting pieces and the fin rays there are usually movable joints. The ventral fins are fastened beneath the pectoral fins, an arrangement which facilitates quick turning.

The propelling muscles and their bony supports are extended along the sides of the backbone and outside the ribs. The ribs enclose the stomach, intestines, and other vital organs. These extract from the food the energy which is given out in muscular exertion. The region of the gills is covered by an elaborate system of jointed plates.

The mouth is guarded by bony jaws which are attached to the lower side of the skull.

each of the gills, in whose filaments it is relieved of its carbon dioxide. Then laden with oxygen it flows into a dorsal artery with branches to all the muscles and internal organs where it exchanges this oxygen for carbon dioxide. The blood which flows to the digestive organs receives the digested food stuffs which they have prepared, and passes through the liver and so back to the auricle of the heart. The blood from the muscles returns to the heart by the caudal vein and other smaller veins.

Thus it happens that the heart is always pumping blood that is rich in nutrients and carbon dioxide but poor in oxygen. The course of the blood stream is from the ventricle of the heart, to gills, to general circulation and digestive organs, to liver, and back to auricle of the heart again. A part passes through the kidneys each time, where urea and other wastes are removed.

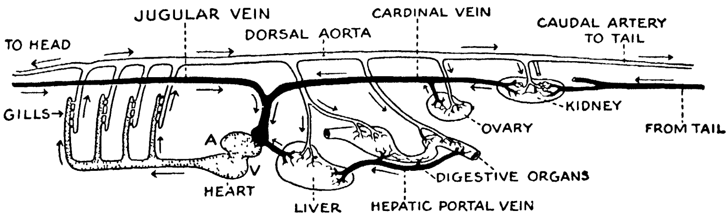


FIG. 104. Diagram showing the circulation in the fish. Note that the blood flows in a single circuit, from body to heart, to gills and to body again.

Nervous System. The central nervous system in all vertebrates is located in the dorsal body cavity, protected by outgrowths from the spinal column. This arrangement is entirely different from that found in the invertebrates, where the nervous system lies along the ventral side and is not so completely separated from the other internal organs.

In the case of most fishes the nervous system consists of the spinal cord, extending the whole length of the body, protected by arches of bone attached to each vertebra. From it many nerves extend to the muscles and internal organs. At the anterior, the cord enlarges to form a brain, entirely different in structure from the so-called brains of the lower forms, in that it has developed separate regions for different functions. The fish's brain consists of five principal parts. Beginning at the anterior, come the olfactory lobes from which the nerves of smell extend to the nostrils. Posterior to these, and considerably larger, are the two lobes of the cerebrum, which control the voluntary muscles of the animal. The largest parts of the brain are the two optic lobes connected directly with the eyes and concerned, of course, with the sense of sight. Behind them comes the cerebellum, and finally the enlarged end of the spinal

cord, the medulla, both of which have to do with regulating muscular action and the work of the internal organs. The medulla is also a region from which branch many important nerves.

The brain as a whole, compared with other vertebrates, is not highly developed. The cerebrum, the center of voluntary control, is actually smaller than the optic lobes, and the whole brain does not fill the cranium or skull cavity, which is partly occupied by a protective liquid. It is only when compared with the invertebrate forms, that the real advance of the fish brain can be realized. In them there were no special parts for separate uses, no division of labor or specialization, and so a highly developed instinct was the best such a brain could achieve.

In the vertebrate, the development of specialized parts of the brain, though very primitive at first, paved the way for a cerebrum which would exceed all the other brain regions in bulk, and control not only voluntary motion, but thought and reason as well. So when studying the simple brain of the fish, do not forget that it contained the possibilities of great advance. It is along this line that the highest vertebrate development has been attained.

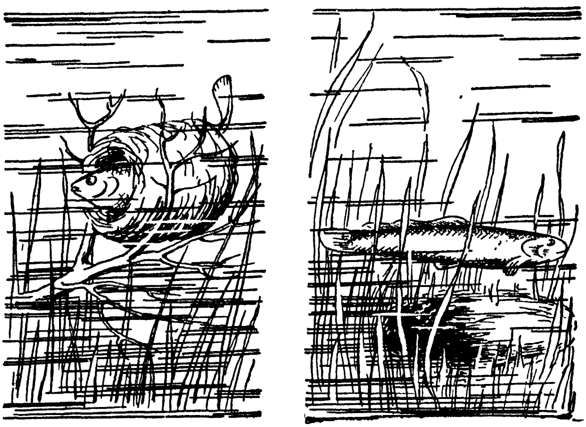
Air Bladder. Another organ, simple in the fish, but which has a great future before it, is the air bladder which is found in most species. This consists of a thin-walled elliptical sac, located in the dorsal part of the body cavity and sometimes connected with the throat by a tube. Its function is to assist the fish in maintaining a level in the water; by contraction of its walls the fish can sink, and by expansion, rise without other effort.

It develops in the embryo fish as an outgrowth from the throat, extending back and enlarging into the present form, and often losing all connection with the outer air. It is in precisely similar manner that the lungs of all higher forms push out from the throat, while retaining their connection with the mouth and performing an entirely different function. Yet they are regarded as of like origin and structure, so the lungs are homologous to the air bladder of fishes, but by no means analogous (or like in function).

In this connection it is interesting to note that in certain Australian fishes the air bladder is actually used as a lung and the gills are poorly developed for breathing.

As the development of higher forms goes on, the simple air bladder becomes two lobed, its walls develop ridges, and finally many-celled chambers which enormously increase the interior surface. To the walls of these delicate cells a network of capillaries brings the blood, and devices are provided to pump air in and out. Thus from the air bladder of the fish, the lung of a bird or man may trace its origin.

Life History. The breeding habits of fish vary so greatly that it is difficult to make any general statements about their life history to which there will not be many exceptions.



From Pearse.

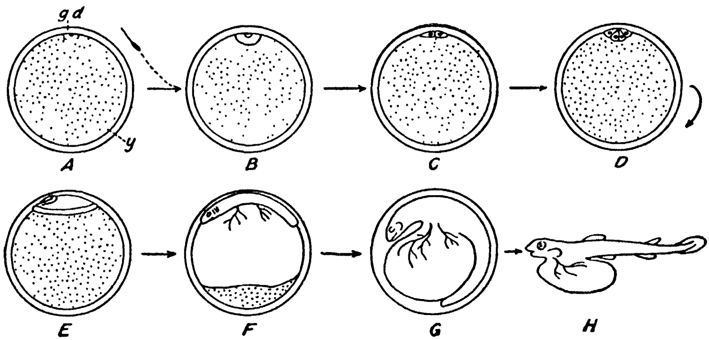
FIG. 105. Fish nests.

Stickleback Dogfish

The eggs vary in size from over an inch in the skate, to the microscopic eggs of the herring. Their number may vary from five hundred in the trout to millions in cod, sturgeon, or flounder. The eggs are fertilized after being laid, by means of the spermatic liquid (milt) which the male sprays over them, sometimes stirring the eggs and milt together so that more shall be fertilized. There is little chance that all the eggs will be fertilized,

since, as in the plant, a sperm cell must reach each egg cell if it is to develop. Hence the large number of eggs is partly to make up for the small chance of fertilization. The eggs and young are prey to many other fish and similar enemies. Man destroys the adults for food, fertilizer, and fun. Out of enormous numbers of eggs, so few survive, in some cases, that artificial culture has to be utilized to prevent total destruction of certain species. In many cases both the fertilization and the care of young are left to chance. In others, such as the bass, sunfish, trout, and catfish, a sort of nest is made on the stream bottom, where the eggs are guarded by the male, or may be covered with sand for protection.

As development proceeds the form of the embryo fish may



From Pearse.

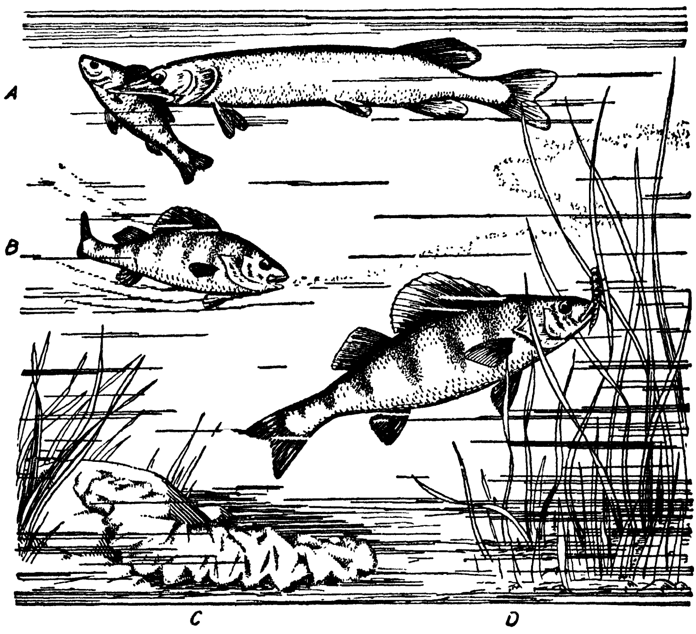
FIG. 106. Early life history of a fish. *A*, unfertilized egg;—gd, germinal disc which contains the nucleus; y, the yolk composed of stored nourishment. *B*, fertilized egg;—formed by union of sperm (at left), and egg nucleus. *C* and *D*, stages in cell division as embryo begins to develop. *E*, embryo showing further development. *F*, embryo larger, yolk nearly surrounded by an absorbing membrane from embryo. *G*, embryo with complete "yolk sac." *H*, young fish just hatched, yolk sac not yet absorbed.

be seen within the egg from which it soon emerges, retaining the yolk of the egg attached to the body, to be absorbed as nourishment until the tiny fish can shift for itself, and grow gradually to its normal size.

Life History of the Salmon. While no one fish can be taken as a type of all, the life history of the Pacific salmon is as well known as any and since it is so familiar an

article of food, we shall take up its breeding habits somewhat in detail.

The adult salmon lives in the ocean all along the northern Pacific coasts. In spring or early summer both sexes migrate in enormous numbers up the Columbia and other rivers often to a distance of hundreds of miles. It is during these "runs" that the canners make their annual catches by means of barriers or machines which scoop up the passing fish.



From Pearse.

FIG. 107. Events in the life of a perch. *A*, caught by a pickerel; *B*, catching small animals for food; *C*, an egg mass; *D*, catching a young dragon-fly nymph.

This migration may be for the purpose of finding greater safety, cooler water, or better food, or it may be a relic of a time when they were entirely fresh-water fish. At all events they begin in March to make their last journey. Slowly at first and later many miles per day they work their way against the current to the spawning beds far from the sea.

Here, in water not warmer than 54 degrees, each female deposits about 3500 eggs. The male spreads over them the "milt" or spermatic fluid at large in the water. It is much like wind pollination in flowers and many eggs are not reached by the sperms, hence do not develop.

The males are brilliantly colored at the breeding season but both sexes soon lose their beauty and strength, partly in fighting other fish and partly by injuries from the stones in the spawning beds.

The eggs are deposited on fine gravel the process extending over several days after which the strength of the parents seems to be exhausted and both die.

After from thirty to forty days the eggs hatch, but as usual with fish, the yolk remains attached until all is absorbed in growth and the fry, as they are called, can shift for themselves.

Although many young salmon fall prey to other fish the majority find their way back to the ocean where they reach adult life, and, if they escape the canner's machines, live to repeat the self-sacrifice of their parents.

Adaptations. The study of the fish reveals an animal, first of all adapted for aquatic life, and nearly all features of its structure and habits tend to this result, as the following summary will show.

Summary of Adaptations

For Locomotion in Water.

1. Shape of body, slimy secretion.
2. Scales, fins.
3. Flexible spinal column and powerful muscles.

For Life in Water (see above, also).

1. Gills for respiration.
2. Air bladder, to regulate depth.
3. Lateral line to determine pressure, and vibration.
4. Structure of eye, spherical lens.

For Protection.

1. Color, dark above, light below.
2. Scales, spines, teeth, slimy secretion.
3. Speed, to escape enemies.

For Food Getting.

1. Location and size of mouth.
2. Shape and location of teeth.
3. Wide gullet and powerful digestion.
4. Speed.

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SUMMARY OF CHAPTER XXVII

FISHES

1. Characteristics.

a. Bony skeleton.
b. Gills.
c. Scales.
d. Fins.

2. External structure.

a. Shape (spindle outline for easy swimming).
b. Scales (for protection and ease of motion) (cf. crayfish).
c. Head.
  (1) Mouth and teeth (for prehension and defense).

- (2) Nasal cavities (for smell, not breathing).
- (3) Eyes, with lens, cornea, etc., but no lids (cf. crayfish).
- (4) Ears, internal (detect vibration or balance).

d. Gills.
- (1) Gill openings.
  - (a) Two.
  - (b) At sides of head.
- (2) Operculum (cover over gills).
- (3) Gill arches.
  - (a) Four.
  - (b) Bony.
  - (c) Hook-shaped.
  - (d) Support the filaments.
- (4) Filaments.
  - (a) Numerous.
  - (b) Much surface.
  - (c) Thin.
  - (d) Capillaries.
- (5) Gill rakers.
  - (a) Clean and spread arches.

e. Trunk.
- (1) Lateral line (for depth sense).
- (2) Fins (a double membrane supported by rays).
  - (a) Paired.
    1. Pelvic (posterior) (for locomotion and balance).
    2. Pectoral (anterior) (for locomotion and balance).
  - (b) Median.
    1. Caudal (tail) (for locomotion and steering).
    2. Dorsal (back) (for steering).
    3. Anal (vent) (for steering).
- (3) Body very muscular.

3. Internal structure.

a. Digestive system.
- (1) Teeth (for prehension, not chewing).
- (2) Stomach (with powerful fluids).
- (3) Intestine (short and large).
- (4) Liver (large).

b. Circulation.
- (1) Heart.
  - (a) Two-chambered.
  - (b) Anterior.
  - (c) Ventral.
- (2) Blood.
  - (a) Flows to gills, to body, to heart, to gills, etc.

c. Nervous system.
- (1) Brain.
  - (a) Separate parts for different functions.

(2) Spinal cord.
(a) Dorsal.
(b) Protected by vertebræ.
d. Air bladder.
(1) Outgrowth from throat.
(2) Function.
(a) To regulate depth.
(3) Homologue of lung.

4. Life history.

a. Eggs.
(1) Small and numerous (Why?)
(2) Externally fertilized.
(3) Slight parental care.
(4) Many enemies.
b. Embryo.
(1) Retains yolk sac for food.
(2) Grows gradually, not by stages (Why?)
c. Life history of the salmon.

5. Adaptations (see summary in text).

CHAPTER XXVIII

THE FROG AND ITS RELATIVES

Vocabulary

Vegetarian, using vegetable food.
Carnivorous, using animal food.
Pulmonary, pertaining to the lungs.
Aerated, supplied with air.
Viscera, all the internal body organs.

The Amphibia

Particular interest attaches to this group because of the fact that, in their life history, we can see the steps in development between the fishlike animals adapted solely for aquatic life and the land animals which cannot live under water.

In this transition from water to land forms, many strange combinations of gills and lungs, fins and legs, have occurred, gills being found on animals with legs, and fins sometimes accompanied by lungs. All together this is a very good object lesson in the development and adaptations of animal forms.

The name amphibia, meaning "having two lives," refers to the fact that they usually are aquatic, fishlike animals when young, and abandon that manner of life for the land when they become adults. This series of changes is called a metamorphosis, just as was the life history of some insects.

Characteristics. The characteristics of the group may be summarized as follows, though there are some exceptions:

1. They undergo a metamorphosis.
2. Eggs are directly fertilized as laid.
3. Body usually covered by a smooth skin.
4. Larval forms are vegetarian; adults, carnivorous.
5. The heart is three chambered, and circulation well developed.
6. The brain, especially the cerebrum, better developed than in fish.

Among the representatives of this curious group are several common animals. Frogs, "tree-toads," toads, newts, and salamanders are all familiar both by sight and sound.

The Frog. The frog will be taken as a type not only because common and convenient, but also because of the resemblance of its structure to that of the human being.

In the work with the frog, it is particularly desirable to compare its structure and development with that of the fish, whenever possible, noting those points in which it is more highly developed and the differences which its land life has made necessary in its structure.

External Features. The frog's body is short, broad, and angular, evidently not as well adapted for submarine locomotion as the fish, nor has it achieved the graceful form of a highly specialized land animal. The covering is a loose skin, colored to resemble its surroundings, and provided with no scales nor hairs, but supplied beneath with many blood capillaries. It is evident that the skin is not for defense like the scaly armor of the fish but attains somewhat the same end by its protective coloration. Its thinness and rich blood supply permit a certain amount of respiration to take place through it. Many amphibians absorb water through the skin instead of by drinking. Some secrete a slimy mucus which assists in locomotion and escape from enemies. The head is broad, flat, and attached directly to the body. The nostrils are located near the anterior and connect directly with the mouth cavity, thus permitting them to be used for respiration. They can be closed by a valve-like flap when under water.

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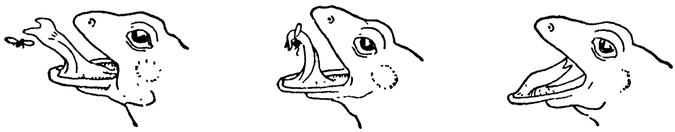
FIG. 108. The frog at rest in the water. Note the advantage gained by the projecting eyes.

Head Structures. The Mouth. The mouth is enormous and extends literally from ear to ear. This is a very necessary adaptation for food-getting as the insects which constitute its



(*Adaptation from Cambridge Nat. His.*)

FIG. 109. Stages in the operation of the frog's tongue in catching insects. The tip is two lobed and sticky, the mouth very wide, and the speed of the tongue is so great as almost to escape the sight. Usually the frog jumps at the same time that it extends its tongue, thus increasing its range. Toads have this same adaptation, and some salamanders are even better equipped.

principal diet have to be snapped up in this veritable trap. Another striking adaptation for the same purpose is the arrangement of the tongue. This is attached at the *front* of the lower jaw, is very muscular, and has two sticky fingerlike projections at its tip. This peculiar tongue can be flipped out of the mouth so quickly that the eye cannot see the motion; the insect sticks to it and is instantly thrown back within the capacious jaws, just where a set of teeth on the roof of the mouth will hold and crush it. There are no teeth on the lower jaw, as they would interfere when the tongue was thrown out over them. Those on the upper jaw are small, and in toads both sets are lacking entirely, as the real organ of prehension in either case is the remarkable tongue.

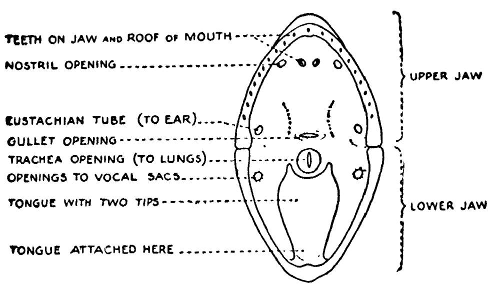


FIG. 110. Internal features of the frog's mouth. The mouth is shown as if opened quite flat. There are no teeth on the lower jaw, as they would interfere with the tongue when extended. The teeth on the roof of the mouth are just where they will catch any insect which has been flipped into the mouth by the tips of the tongue. The openings into the vocal sacs enable the frog to inflate his throat and, with these hollows as a sounding board, make such loud calls in the mating season. Notice that the food has to pass *over* the trachea to reach the gullet, so the former is protected by a sort of lip-like valve.

As we look inside the frog's mouth the nostril openings can be seen near the anterior of the upper jaw; the tongue folded back occupies the floor of the lower jaw; farther back at the sides are the openings of the Eustachian tubes from the ears; and at the extreme rear, in the middle, can be found the wide gullet and slit-like opening of the breathing tube or trachea. The walls of the throat are loose and can be greatly expanded with air when the frog is calling, thus acting as resonating chambers. This gives great volume to the sound for which all frogs are noted.

Other Organs. The *eye* of the frog is one of the most beautiful in all the animal kingdom, having the black pupil surrounded by a handsome bronze colored iris of large size. It projects conspicuously from the top of the head, but can be withdrawn, level with the skull. It is protected by lids and an extra covering, the *nictitating membrane*, which can be raised from below and probably protects the eye when under water.

The location of the *nostrils* at the very tip of the head, and the high projection of the eyes enable the frog both to see and breathe while the rest of the body is covered by water. When in this position they are able to avoid observation, and so escape from large water birds which feed upon them.

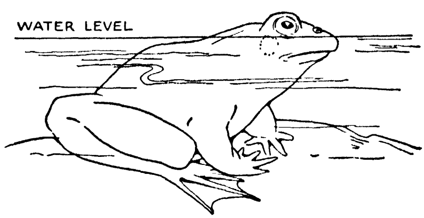


FIG. 111. Frog at rest in water. Note that eyes and nostrils are out of water while rest of body is submerged: a protective adaptation.

The *ears* are located just behind the eyes and consist, externally, of the round tympanic membrane, which is connected with the internal ear beneath and also with the mouth cavity, by means of the Eustachian tube.

Legs. The anterior legs are short and weak. They are provided with four inturned toes, which help little in locomotion but serve as supports to the body when on land. The hind legs, however, are enormously developed and adapted in several ways for leaping and swimming. The thigh and calf

muscles are very powerful and are so attached to the hips that they move the legs as very efficient levers, in locomotion. Added to this is the great development of the ankle region and toes, which together are longer than the lower leg and add greatly to the leverage of these organs. Between the five long toes is developed a broad flexible web membrane, which accounts for the frog's notable ability as a swimmer.

Some frogs can leap fifty times their own length or twenty times their height, while a man, to equal this feat would have to make a broad jump of three hundred feet or clear the bar at a height of one hundred and twenty feet.

The legs of the frog are homologous to the paired fins of the fish but resemble much more closely our own arms and legs. A study of a prepared skeleton of the frog shows that the foreleg has the same regions as our arm. The hind leg even more closely resembles our leg, though with many differences due to being adapted for very different functions. Still the homology is plain as the following table shows:

COMPARISON OF APPENDAGES OF FROG AND MAN

Front leg and arm	Frog	Man
Upper arm (humerus)	Short and weak	Long and muscular
Lower arm (radius and ulna)	Short, bones united	Long, bones separate
Wrist (carpus)	Very short, stiff	Longer and flexible
Hand (metacarpus)	Turned inward	Straight
Fingers (phalanges)	Four, short and weak	Five, long and flexible
Hind leg and leg		
Upper leg (femur)	Very long and muscular	Medium length, not so muscular in proportion
Lower leg (tibia and fibula)	Very long, bones united	Medium length, bones separate
Ankle (tarsus)	Very greatly lengthened	Short
Foot and toes (metatarsus and phalanges)	Five, very long webbed toes	Five short toes, not webbed

Not only are the regions and the bones similar in general structure, but many of the muscles, blood vessels, and nerves

of the limbs of man and frog are of similar form and name. The chief difference lies in the fact that man has developed his fore-legs into organs for prehension (grasping) and no longer uses them in locomotion. This has resulted in his erect position and has produced many changes in structure to adapt the arm and hand for its altered function.

The muscles of the fish are in the form of flat plates, extending across the body and moving it as a whole, while in the frog, the muscle tissue is grouped into true "muscles" like our own, attached to bones by tendons, and acting on them as levers, thus marking a great advance in structure, and permitting greater variety of motions.

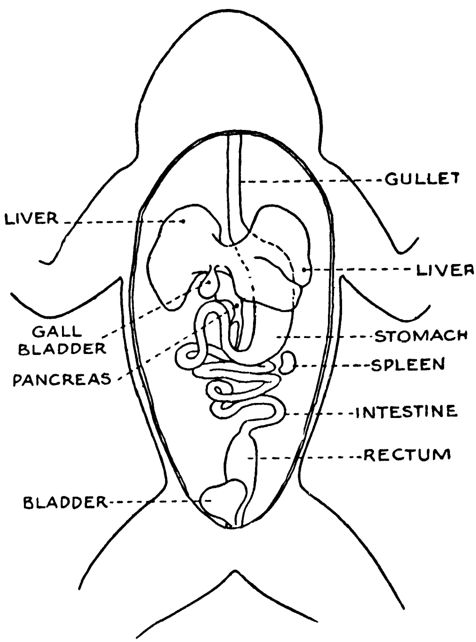


FIG. 112. Digestive organs of the frog.

The Digestive System. The digestive system of any animal begins with the mouth, teeth, and food-getting adaptations which we have already described in this case.

A short gullet connects the large mouth cavity with the stomach which is an oval enlargement of the digestive tube, set diagonally in the body cavity and partly covered by the liver which is anterior and ventral to it. Continuing from the stomach is the intestine, of medium length, coiled, and enlarging near the vent into a short, broad rectum and cloaca. The digestive tract is longer than that of the fish, the absorbing surface being increased by the coiled intestine.

Connected with the food tube are the usual digestive glands, the salivary and mucous glands in mouth and gullet, gastric glands in the walls of the stomach, and the large liver and smaller pancreas opening into the intestines.

Here as usual we have the essential features of any vertebrate digestive system: a tubular canal, provided with large extent of surface for absorption by osmosis, and a series of glands which secrete the fluids used to get the food into soluble form for this absorption.

Circulatory System. In so complicated an animal as the frog, it would be expected that the circulatory system would need to be better developed than in the fish, especially as the lungs are present for the first time, to purify the blood. To provide for this added burden, we find a three-chambered heart located well forward in the body cavity, and consisting of two auricles and one muscular ventricle. Extending from the ventricle is a large artery which at once divides in two branches like a letter Y and each of the arms again divides into three separate arteries on each side. The anterior pair of these branches (the carotids) carries blood to the head; the middle pair arch around to the back of the body cavity and unite to form the dorsal aorta which supplies the muscles and viscera; while the posterior (pulmonary) arteries carry the blood to the lungs and skin for purification.

The blood supplied to the muscles returns laden with carbon dioxide and other oxidation products, while that going to the digestive tract takes up the digested foods as well. It returns by way of the veins, in part to the liver, and, finally, all to the right auricle of the heart. Meanwhile the blood which went to the lungs and skin has been relieved of its carbon dioxide and resupplied with oxygen. This returns by the pulmonary veins to the left auricle of the heart. The blood from both the general and the pulmonary circulation then enters the ventricle, but by means of a complicated valve, that having most oxygen is sent to the head and brain. The next best goes out into the aorta, while that with most carbon dioxide is diverted into the pulmonary arteries and goes to the lungs and skin.

On each complete trip, some of the blood passes through the kidneys, so that all of the nitrogenous waste can be removed as urine. Really the purest blood in an animal's body is that which has just left these very important organs, even though it may have more carbon dioxide than when leaving the lungs.

The blood which returns from the digestive tract is gathered into a large vein (portal) and passes through the liver, where some food substances may be stored, and certain impurities removed, after which it flows back to the right auricle.

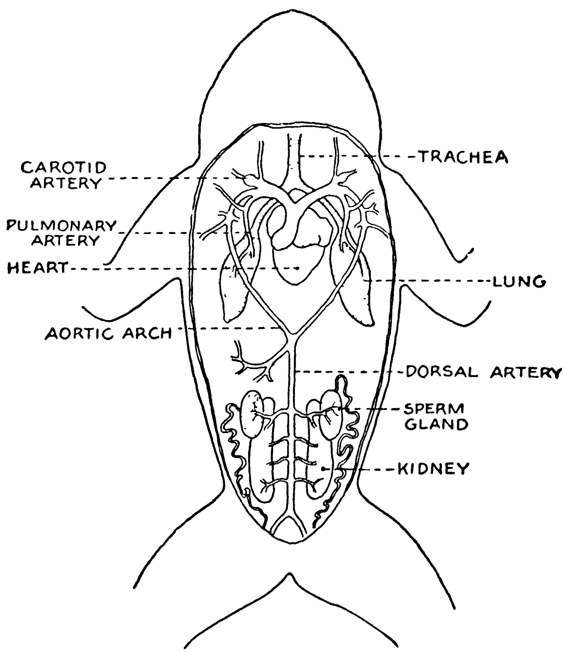


FIG. 113. Arterial circulation in the frog.

Several important differences will be noted in the frog's circulatory system, as compared with the fish. The frog's heart is three chambered and is located farther back in the body; the blood leaves the heart in *two* circuits, the pulmonary and the general, while in the fish, it makes only one continuous trip.

In other words, the blood twice returns to the heart of the frog in any single complete circulation, and only once in the fish.

Respiration. In the larval form, as a tadpole, the young frog breathes by means of gills but the adult develops a pair of simple lungs, opening into the throat by a trachea and glottis. These lungs are rather cone-shaped, sac-like organs whose inner walls are honey-combed with delicate air cells provided with many blood capillaries so that the conditions for osmosis are fulfilled.

The frog has no ribs or diaphragm to expand the lungs so that air may come in, and is therefore forced to "swallow" whatever air it gets by a sort of pumping motion of the throat which can be observed in any living frog. Air is taken in through the nostrils, which are then closed and the air "swallowed" into the lungs by the action of the abdominal muscles. The elasticity of the lung tissue forces the air out again. The slight throbbing of the throat is not breathing; it merely pumps air in and out of the mouth. When air is really "swallowed" the sides of the body expand and the floor of the mouth rises. Then the expired air is forced back into the mouth where the constant pumping, above mentioned, gradually replaces it with fresh air, which is then swallowed and the process repeated.

Considerable blood is aerated by the capillaries in the skin, which act as a sort of gill, obtaining dissolved oxygen when the animal is under water. This is an evident adaptation for its amphibious life.

Nervous System. The nervous system shows considerable advance over that of the fish. The cerebrum is larger compared with the other brain parts. The brain as a whole is more specialized and more nearly fills the cranial cavity of the skull; while the spinal cord is shorter, thicker, and has its branches arranged much more like those of the higher animals.

Observation of the living frog shows that all the senses are fairly developed except possibly that of taste. Sight and hearing are probably good, and its varied life on land and water necessarily presents a wider range of experience and hence some advance in intelligence.

Excretory System. Excretion is provided for by a pair of

well-developed kidneys with a large bladder. Water, uric acid, and other nitrogenous waste are removed by these organs, while the lungs and skin also help dispose of waste matter, particularly carbon dioxide and water.

Reproduction. As in the fish, the sexes are separate, and the reproductive organs are easily found upon dissection. The ovaries usually appear as masses of eggs, the size depending on the season of year. The sperm glands of the male are small oval organs near the kidneys. Both sets of organs have coiled ducts which eventually connect with the posterior part of the intestine (cloaca) into which the bladder also empties.

Systems of Organs. It may be well to remember that in the frog we find systems of organs adapted to perform all the life functions, and that in the higher animal forms, few new structures are developed, but rather, these are carried to a greater complexity or perfection.

The following list illustrates this and would apply in general to most vertebrate animals.

1. Digestive system.
   Mouth, tongue, teeth, throat cavity, salivary glands.
   Gullet and stomach, gastric glands.
   Intestine, small and large, rectum, and cloaca.
   Liver and gall sac, pancreas.
2. Respiratory system.
   Nostrils, mouth cavity, glottis, and trachea.
   Lungs, air cells, and capillaries.
   Skin.
3. Circulatory system.
   Heart, auricles, and ventricle.
   Arteries, aorta, etc.
   Capillaries, and veins.
   Lymph vessels, and spleen.
4. Excretory system.
   Kidneys, and their ducts (ureters), bladder.
   Lungs, and skin.
5. Nervous system.
   Brain: consisting of
      Olfactory lobes.
      Cerebrum.
      Optic lobes.
      Cerebellum.
      Medulla.

Spinal cord and nerves.
Sense organs, eye, ear, etc.

6. Supporting system.
   Skeleton, bone, and cartilage; ligaments.
   Connective tissue.
7. Muscular system.
   Body muscles, tendons.
   Muscles of internal organs, heart, intestines, etc.
8. Reproductive system.
   Ovaries and oviducts.
   Spermaries and sperm ducts.

ADAPTATIONS OF THE FROG

	By means of	For the purpose of
External features	Protective color	Escape from enemies
	Shape, and slimy secretion	Locomotion and escape
Head	Large mouth	Catching food
	Location and shape of tongue and teeth	Catching food
	Nostrils at tip of nose	Breathing when partly submerged
	Projecting eyes	Vision when partly submerged
Limbs	Short fore limbs	Landing after leaping
	Long hind legs	Increasing leverage for leaping
	Very long feet and toes	
	Powerful muscles	Leaping and swimming
	Webbed toes	Swimming
Digestive organs	Gullet and mucous glands	Swallowing
	Stomach and gastric glands	Digesting proteins
	Intestine, liver, and pancreas	Digesting and absorbing all food stuffs
Circulatory organs	Three chambered heart	Forcing blood through body
	Veins	Bringing blood to heart
	Arteries	Carrying blood from heart
	Capillaries	Distributing blood to the tissues
	Blooa	Transportation of food, oxygen, waste, CO_2
Respiratory organs	Gills in tadpole	Absorbing dissolved oxygen
	Two lungs in adult	Absorbing free oxygen
	Lung lining cellular	Increase of absorbing area
	Rich blood supply	Carrying oxygen, etc.
	Throat and body muscles	Taking air into lungs
	Thin vascular skin	Additional breathing when submerged

COLLATERAL READING

General Structure: *Economic Zoölogy*, Kellogg and Doane, pp. 1–13; *Economic Zoölogy*, Osborne, pp. 356–374; *Biology of the Frog*, Holmes, entire; *Types of Animal Life*, Mivart, pp. 96–122; *Forms of Animal Life*, Rolleston, pp. 74–81; *Winners in Life's Race*, Buckley, pp. 70–88; *Reptiles and Birds*, Figuier, pp. 17–33; *The Animal World*, Vincent, p. 25; *The Frog Book*, Dickerson, pp. 171–185; *U. S. Fish Commission Report*, 1897, pp. 251–261; *Zoölogy Textbook*, Davenport, pp. 325–348; *Familiar Life*, Matthews, pp. 1–56; *Talk about Animals*, pp. 151–154, 160–164; *Wilderness Ways*, Long, pp. 75–87; *General Zoölogy*, Colton, pp. 181–195; *Zoölogy Textbook*, Linville and Kelly, pp. 327–347; *Biology of Man and Other Organisms*, Linville, pp. 92–101; *Practical Zoölogy*, Hegner, pp. 245–267; 299–308.

SUMMARY OF CHAPTER XXVIII

AMPHIBIA

1. **Characteristics.**
    - a. Metamorphosis.
    - b. No scales.
    - c. Three-chambered heart.
    - d. Fairly developed brain.
    - e. Direct fertilization.
    - f. Larva, vegetarian.
    - g. Adult, carnivorous.

2. **Representatives.**
    - a. Salamanders.
    - b. Toads.
    - c. Newts.
    - d. Tree-frogs.
    - e. Frogs.
        - (1) External structure.
            - (a) Shape.
                - 1. Irregular.
                - 2. Not graceful.
            - (b) Covering (loose, smooth skin).
                - 1. Absorbs water.
                - 2. Adaptations.
                    - a. For protection.
                        - (1) Color.
                        - (2) Slime.
                    - b. For respiration.
                        - (1) Capillaries.
                        - (2) Thinness.
            - (c) Head (no neck).
                - 1. Nostrils.
                    - a. Anterior.
                    - b. Connect with mouth.
                    - c. Valve.
                - 2. Mouth (large, for catching insects).
                    - a. Tongue.
                        - (1) Fixed in front.
                        - (2) Two tips.
                        - (3) Sticky.
                    - b. Teeth.
                        - (1) None below.
                        - (2) Small on upper jaw and roof.

c. Interior structure.
(1) Nostril openings.
(2) Folded tongue.
(3) Eustachian tubes.
(4) Gullet.
(5) Trachea.
3. Eyes.
a. Large.
b. Projecting.
c. Can be retracted.
d. Three lids.
4. Ears.
a. Flat drum on surface of head.
(d) Legs.
1. Anterior.
a. Short.
b. For support only.
2. Posterior.
a. Long.
b. Strong.
c. For leaping and swimming.
3. Adaptations.
a. Powerful calf and thigh muscles.
b. Long levers (especially ankle and toes).
c. Webbed toes.
d. Large hip bones.
4. Comparison with fins of fish.
a. Legs homologous to paired fins of fish.
b. Legs and fins analogous (locomotion).
5. Comparison with legs of man (see text).
a. Legs homologous to legs and arms of man.
b. Legs and arms not analogous (prehension and locomotion).
(e) Muscles.
1. Spindle-shaped as in higher animals.
2. Attached to bones with tendons.
3. Not in separate plates like the fish.
(2) Internal structure.
(a) Digestion.
1. Food-getting adaptations.
a. Tongue.
(1) Attachment.
(2) Shape.
(3) Sticky.
b. Teeth.
(1) Upper jaw and roof of mouth.
c. Mouth.
(1) Location.
(2) Size.
2. Organs of digestion.
a. Gullet.
(1) Short and broad (Why?)

b. Stomach.
(1) Oval.
(2) Diagonal.
(3) Covered by liver.
c. Intestine.
(1) Medium length.
(2) Coiled (Why?)
(3) Rectum.
d. Glands.
(1) Salivary and mucous in mouth.
(2) Gastric and mucous in stomach.
(3) Liver and pancreas emptying into intestine.
3. Essentials for digestive system.
a. Tubular canal.
b. Glands for secretion.
c. Devices to increase surface (for osmosis absorption).

(b) Circulation.
1. Heart.
a. Location.
b. Three chambers.
(1) Two auricles.
(2) One ventricle.
2. Arteries (carry blood from the heart).
a. Carotid.
(1) From ventricle to head.
(2) Oxygenated blood.
b. Aorta.
(1) From ventricle to body.
(2) Oxygenated blood.
c. Pulmonary.
(1) From ventricle to lungs.
(2) De-oxygenated blood.
3. Veins (carry blood toward the heart).
a. Portal-caval.
(1) From digestive system to right auricle.
(2) De-oxygenated.
b. Caval.
(1) From muscles, etc., to right auricle.
(2) De-oxygenated.
c. Pulmonary.
(1) From lungs to left auricle.
(2) Oxygenated.
4. Blood.
a. Blood changes in lungs.
(1) Relieved of water and carbon dioxide.
(2) Receives oxygen.

b. Blood changes in kidneys.
   (1) Relieved of water, urea, salts.
c. Blood changes in liver.
   (1) Relieved of impurities and bile.
   (2) Sugar changes.

5. Advance over fish.
   a. Three-chambered heart.
   b. Two circuits of blood.
      (1) Pulmonary.
      (2) General.
   c. Lungs instead of gills.

(c) Respiration.
1. By gills in larval stage, later by lungs.
2. Lungs.
   a. Shape.
   b. Location.
   c. Wall structure.
      (1) Air cells and capillaries (Why?)
   d. Action of lungs in breathing.
      (1) Air pumped into mouth by throat and swallowed.
      (2) No diaphragm (cf. man).
      (3) Air exchange in mouth and nostrils with valves.
3. Use of skin.
   a. Adaptation for breathing.

(d) Nervous system.
1. Brain.
   a. Larger.
   b. Specialized parts.
   c. Nearly fills skull.
2. Spinal cord.
   a. Thicker.
   b. Shorter.
   c. With specialized branches.
3. Senses.
   a. Better.
   b. Higher intelligence (Why?)

(e) Excretion.
1. Kidneys.
   a. Shape.
   b. Location.
   c. Function.
2. Lungs.
   a. What excreted?
3. Skin.
   a. What excreted?

(f) Reproduction.
1. Ovaries.
2. Sperm glands.
3. Ducts.

CHAPTER XXIX

THE AMPHIBIA, LIFE HISTORY AND HABITS

Vocabulary

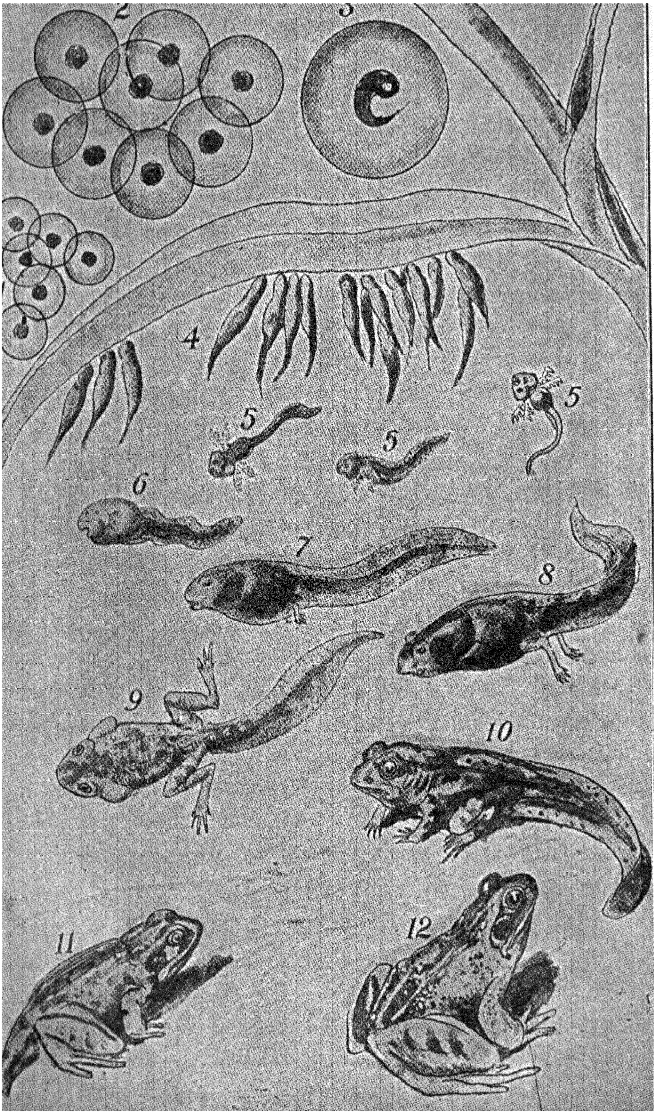
Caudal, pertaining to the tail.
Cellular, composed of cells.
Hibernate, to remain inactive over winter.
Vicissitudes, changes and accidents of life.

Life History. The life history of a frog is a true metamorphosis and illustrates perfectly the development of an air-breathing land animal from a gill-using aquatic form.

The female lays the eggs in the water, early in the spring, and they are fertilized immediately, thus assuring more certain development than in the case of most fish. Each egg is surrounded by a jelly-like coat which swells in the water until all are joined in a gelatinous mass. In this, dark-colored eggs about as large as peas can be seen, each surrounded by a transparent covering. The rate of embryo growth depends somewhat upon temperature and food conditions but usually the parts can be distinguished within each egg in less than ten days. The little tadpoles themselves leave the mass within two weeks.

At this stage they fasten themselves to stones by means of sucking discs and live by absorbing the attached egg yolk, no mouth being developed. There are three pairs of external gills, a narrow fish-like body, well developed, and a caudal fin.

Next they become free swimmers. The mouth now appears, and a very long coiled digestive tract begins work on the vegetable scums which are their food. Gradually a fold of skin grows backward over the gills, like an operculum, leaving only a small opening on the left side. There is an internal connection to the right gills so that both are supplied with water.



Courtesy of D. Appleton & Company.

FIG. 114. Development of Frog. 1, 2, 3, eggs; 4, young immediately after hatching; 5, tadpole with external gills; 6, 7, 8, 9, 10 and 11, further stages of development; 12, frog. **(From** Baskett and Ditmars' *Story of the Amphibians and Reptiles.*)

These latter changes may have occupied nearly two months, and the tadpole is now a fish-like animal, with gills, lateral line, fins, two-chambered heart, and one-circuit circulation. Soon other changes follow, gradually adapting the aquatic animal for land life.

A sac-like chamber develops backward from the throat like the fish's air bladder, but soon separates into two lobes with cellular walls which we recognize as lungs. To correspond with this, the circulation is gradually modified; the gill arteries are changed to carotids, pulmonaries, and aortic arches; the heart becomes three chambered, and the circulation flows in two circuits. At this stage the tadpole may be seen coming to the surface for air to fill his new lungs as his gills no longer are used for breathing but are being modified into mouth parts and other organs.

While these notable changes are occurring to the respiratory and circulatory systems, others no less remarkable are taking place elsewhere. The mouth widens, teeth develop, and the intestine becomes shorter and larger to adapt it for animal diet which the young frog now begins to use.

The external changes, which have accompanied these last mentioned, have been more conspicuous, though less important, and are as follows. The tail is gradually absorbed (not shed), limbs develop at the place where it joined the body, and the body itself changes shape. The front legs begin growth about the same time but do not show so soon since they start beneath the operculum in the gill chamber and are smaller even when full grown.

By this time, the tadpole is a well-developed frog which comes on land, breathes air, eats animal food and gradually grows in size till he reaches the full stature of an adult. These latter changes have occupied usually another month, making a total of about three months for an average frog metamorphosis, though growth in size may continue much longer.

Representatives. Let us now briefly take up a few of the common representatives of the amphibia, which includes, besides the frog, the toads, salamanders, newts, etc.

Toads. The common toad is a much abused and little appreciated member of society: he suffers from many false accusations and his undeniably plain looks have obscured his many virtues. To begin with, toads do *not* cause warts; they do *not* "rain down"; they do *not* "eat their tails"; and they are never "found alive in solid rock" as some newspaper scientists would have us believe.

On the other hand, the toad is a very useful and interesting animal and makes a good pet. They destroy enormous numbers of harmful insects, though we seldom see them in action as they hunt at night, when their prey is abundant and their enemies, the snakes, are asleep. So valuable is their service in insect destruction that in Europe toads are regularly for sale to gardeners and others, to be turned loose in their premises to protect their crops.

They catch their food with the tongue, like the frog, but have no teeth. Their rough skin and dull color are protective in their resemblance to the earth in which they live. They can change color somewhat to match their surroundings and also will play dead, to escape observation. They never drink water, but absorb it through the skin and may store considerable for use during winter when they burrow in the earth and hibernate. It is this stored water that toads sometimes eject when handled.

They burrow rapidly *backwards* in a way hard to understand and will bury themselves, in a few minutes, if the ground be soft.

They breed in water as do the frogs, but spend the rest of their time on land. They also differ in other ways. The eggs are laid in long strands, not in masses; the tadpoles are small and nearly black and develop into toads at much smaller size than do frogs. They emerge from the ponds in thousands when about the size of the tip of your finger and it is these swarms of tiny toads that give rise to the idea that they have come down in the rain. During the breeding season they develop vocal powers of no mean extent, their song being rather a sweet and bird-like trill.

Their eyes are even more handsome than the frog's. Alto-

gether, the toad is a useful and interesting animal and should never be regarded with repugnance, much less, with enmity.

Tree "Toads." Another member of the amphibia is the tree "toad" or tree frog (Hyla) which, although common, is seldom seen, because of its almost perfect protective coloration. Its song however is familiar enough when the "peepers'" cheerful chorus ushers in the early spring. They vie with the chameleon in ability to change color to match their surroundings, green, gray, brown, yellowish, and even purple being among their varied disguises. It seems hardly possible that so loud a song can be sung by a tiny frog, little more than an inch in length, but if we are patient and successful enough to hunt one out with a lantern at night, the reason is clearer. The little Hyla can expand its throat into a vocal sac twice the size of its head, and with this enormous drum can produce its very remarkable music.

They are true tree climbers and on each toe have sticky discs by which they can climb safely on the bark of trees and even cling to glass. Their color, stripes, and shape protect them perfectly from observation.

The eggs are laid in April; and the tiny reddish tadpoles feed on mosquitoes. The adults include also ants and gnats on their menu, which ought to give them a place in our affection. A curious fact about their tadpole stage is that they often leave the water before the tail is nearly absorbed, being apparently able to breathe air earlier in their metamorphosis than do most other frogs.

Salamanders and Newts. The tailed amphibians, including salamanders, newts, and mud puppies, are less known than they should be. We have over fifty species in the United States, that being more than are found in any other country. A very common mistake is to call these animals "lizards." They can readily be distinguished because a lizard is a reptile and has scales like a snake whereas the salamander is an amphibian and has a smooth skin like a frog.

One often finds, in moist woods, tiny brown or orange red creatures about three inches long, beautifully spotted with

scarlet and black. These are newts and very curious and interesting little fellows indeed. They can only live in moisture, and so are found after rains and in wet places, although in adult form they breathe air. They have the regular amphibian metamorphosis, though they never absorb their tails.

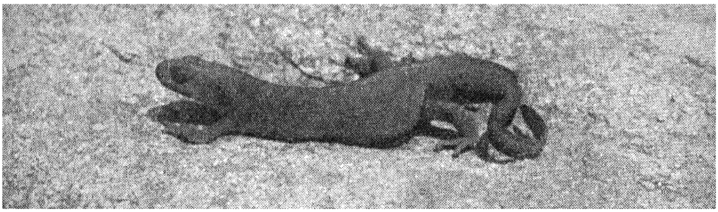


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FIG. 115. Common newt, red (land phase) salamander.

The newt, however, adds a very curious stage to its life history, for after about two years of land life it returns to the water, even from great distances, changes color to olive-green, develops its tail fin again and by some means is enabled to breathe the dissolved air in the water. Here, after all these strange vicissitudes, breeding takes place, eggs are laid, and the life history starts again.

The true salamanders are larger, there being several common species. The spotted salamander, black with yellow spots, is about six and one-half inches long, and the black salamander, blue black and a little smaller, are two of the kinds most often found and mistaken for lizards. All are harmless to handle, useful as insect eaters and so helpless and interesting that they ought never to be destroyed.

COLLATERAL READING

Metamorphosis: *The Frog Book,* Dickerson, pp. 1–7; *Study of Animal Life,* Thompson, p. 258; *Elements of Zoölogy,* Davenport, pp. 451–457; *Textbook of Zoölogy,* Packard, p. 184; *Introduction to Biology,* Bigelow, pp. 389–414; *Lessons in Zoölogy,* Needham, pp. 178–196; *Elementary Zoölogy,* Kellogg, p. 299; *Biology of the Frog,* Holmes, pp. 81–119; *Animal Activities,* French, p. 179; *Zoölogy Text,* Packard, p. 874; *Winners in Life's Race,* Buckley, pp. 70–77; *Cornell Nature Leaflet,* Vol. 10, No. 1, pp. 88–97; *Life in Ponds and Streams,* Furneaux, pp. 360–399.

Relatives: *American Natural History,* Hornaday, pp. 359–374; *Frog Book,* Dickerson, pp. 53–239; *Elementary Zoölogy,* Davenport, pp. 325–348; *Practical Zoölogy,* Davison, pp. 199–211; *Elementary Zoölogy,* Galloway, pp. 296–305; *Pet Book,* Comstock, pp. 246–259; *Handbook of Nature Study,* Comstock, pp. 181–199; *Nature Study Leaflets* (bound), pp. 185–206.

SUMMARY OF CHAPTER XXIX

HABITS OF AMPHIBIA

1. Metamorphosis of Frog.
- a. Introduction.
  - (1) Meaning of term.
  - (2) Other examples.
  - (3) Tadpole is "frog larva."
- b. Egg.
  - (1) Laid in water.
  - (2) Laid in the spring.
  - (3) Sure fertilization.
  - (4) Gelatinous protection.
  - (5) *Parts show in ten days.*
- c. Tadpole, attached stage.
  - (1) Discs.
  - (2) Three pairs external gills.
  - (3) Lives on yolk.
  - (4) *Two weeks.*
- d. Tadpole, free swimmer.
  - (1) Mouth develops.
  - (2) Long intestine because vegetable feeder (explain).
  - (3) Lateral line.
  - (4) Caudal fin.
  - (5) Operculum with left opening.
  - (6) Two-chambered heart (fish-like).
  - (7) *Two months.*
- e. Tadpole, frog.
  - (1) Mouth widens.
  - (2) Intestine shortens.
  - (3) Teeth develop.
  - (4) Heart three-chambered.
  - (5) Arteries change from gill to lung.
  - (6) Lungs develop.
  - (7) Air used.
  - (8) Skin breathing.
  - (9) Tail absorbed.
  - (10) Legs develop.
  - (11) *One month.*
- f. Adult frog.
  - (1.) Total time about three months (depends on food, temperature, etc.).

2. Distinctions between Toad and Frog.

Toad	Frog
Eggs laid in strands	Eggs laid in masses
Get food at night	Get food by day
Tadpoles small and black	Tadpoles larger and lighter color
Teeth lacking	Teeth on upper jaw only
Skin rough	Skin smooth

3. Distinctions between Salamander and Lizard.

Salamander	Lizard
Common in most regions of U. S.	Not common in Northern U. S.
Skin smooth like a frog	Skin scaled like a snake
No claws on the feet	Claws on feet
Metamorphosis like frog	No metamorphosis

CHAPTER XXX

THE REPTILES

Vocabulary

Iridescence, changeable rainbow colors.
Reticulated, marked with a network pattern.
Retracted, drawn back.
Constrictors, snakes that crush their prey in their coils.

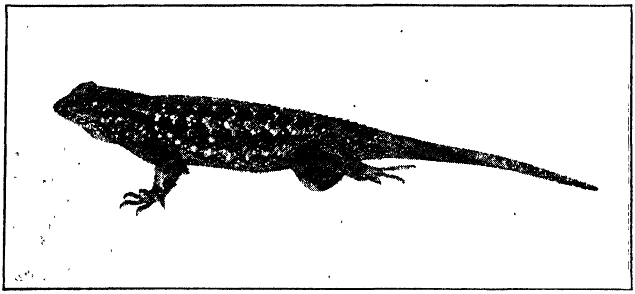
There is probably no group of animals less understood, and concerning which there is more abundant misinformation than the reptiles. It is principally to correct some of these false ideas that they are discussed here.

The reptiles include snakes, turtles, lizards, and crocodiles and the points in which they differ from amphibians are as follows:

1. They never breathe by gills at any stage.
2. They have no metamorphosis.
3. Eggs are internally fertilized and have a shell, or young may be born alive.
4. The body is covered with scales.
5. Feet, if present, are provided with claws.

False Ideas about Snakes. Of all the reptiles, the snakes are the objects of more ignorant superstition and foolish prejudice than any other form. To begin with, snakes are not "slimy" and "nasty." Their skin is usually clean and feels cold merely because of their lower bodily temperature. Snakes as a class are absolutely harmless and positively useful. Out of the numerous species inhabitating the United States only the rattler, copperhead, moccasin, harlequin, and coral snakes, are dangerous to handle. Snakes cannot jump from the ground when they strike nor do they spring from a perfect coil. A snake's tongue is not a weapon nor harmful in any way. The process of death is slow in any animal with a low nervous organism, and

though reflex motions persist in a snake long after death, the setting of the sun has absolutely nothing to do with its death. Snakes do not swallow their young to protect them; "hoop snakes" do not roll like hoops; horsehairs do not turn into snakes; and rattlers do not add one rattle per year, but usually two or three, though some may be broken off. Removal of



From Kellogg and Doane.

FIG. 116. A fence lizard, note scales and claws.

fangs from a poisonous snake does not render it harmless since other teeth take their place almost at once. Many snakes hiss; some as loudly as a cat. Most snakes can swallow prey larger than themselves. All snakes are muscular, graceful, and usually swift of motion, while many are very beautiful.

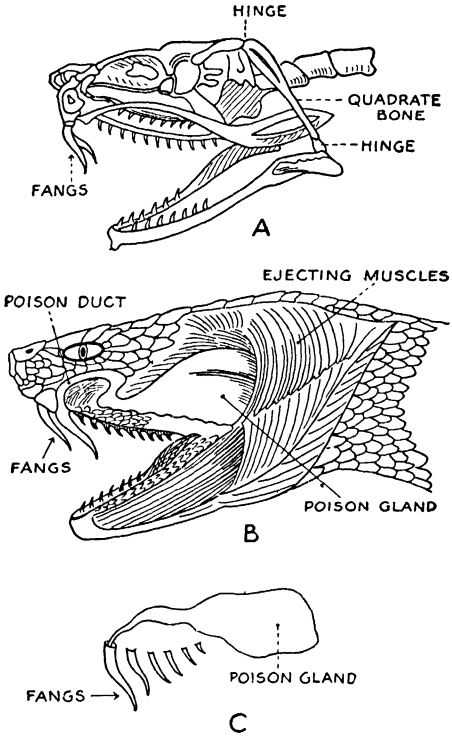
"There is no living creature which displays such a beautiful pattern of colors and rainbow iridescence, as the reticulated Python of the East Indies," says William T. Hornaday.

Children are not born with any natural fear of snakes and adults should never be allowed to terrify their minds with silly snake stories and untrue and ignorant statements.

Adaptations. Another matter which is little appreciated in regard to snakes, is the fact that there is perhaps no other animal, except the bird, with a more highly specialized structure.

The whole animal, but particularly the head, is adapted for its peculiar habit of catching and swallowing prey actually larger in diameter than its own body. For this purpose there are numerous sharp, incurved teeth on three sets of jawbones.

Any of these teeth will grow again to replace those that may be broken or torn out. The lower jaw is not fixed directly to the skull, but is attached to a separate bone, the quadrate, which in turn is attached to the skull, thus permitting the jaw to move forward and backward, as well as up and down. This enables the snake to literally crawl outside of its victim, the upper teeth holding firmly while the lower jaw is advanced; then the upper jaw takes a new hold, and so on. The process is slow, often occupying hours, but there is no chance for escape of the prey. The snake's teeth cannot bite the food in pieces, so all its victims must be swallowed whole. To permit this, various bones of the skull, so solid in other animals, are loosely attached in the snake, allowing the head to



After Linville and Kelly, by permission of Ginn and Co.

FIG. 117. Poison Apparatus of Snake.

A. Shows the structure of the skull. Note the two hinges which permit a forward and backward motion of the quadrate bone. This allows the lower jaw to be extended and drawn back to aid in swallowing the prey.

The very loose attachment of all the skull bones permits great freedom of motion, needed when swallowing a victim larger than itself.

The fangs are grooved or hollow, forming an outlet for the poisonous venom.

B. Shows part of the head dissected away to expose the poison gland and the muscles that press upon it when the snake strikes. The act of striking forces the venom out through the fangs, into the wound.

C. Is a diagram showing the poison gland, duct and fang removed. Also the secondary fangs which develop to replace the large ones, if they are injured or torn out in striking.

expand when swallowing is taking place. The two halves of the lower jaw are attached together, by an elastic ligament which allows them to open sidewise, so that the lower jaw is capable of three motions, up and down, back and forward, and (each half) sidewise.

The process of swallowing is so long that special adaptations are provided to permit breathing to go on. The trachea may be extended along the floor of the mouth, almost to the teeth, so that air may reach the lungs. Moreover there is a large air chamber behind the lung to store air for this purpose.

The gullet and stomach are highly elastic and the digestive fluids very active, to accommodate food in such large doses. The flexible ribs and lack of breast bone or limb girdles allow for the passage of these enormous mouthfuls.

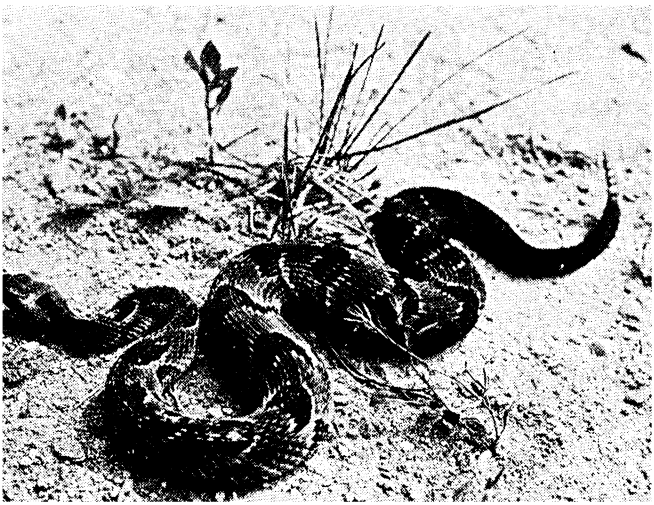
The delicate and slender forked tongue is protected during swallowing by being retracted into a sheath. Its function is for touch or possibly for hearing rather than taste, which sense would be of very little use to an animal which eats its food whole and sometimes alive.

Snakes obtain their food in three general ways: they may catch it with the teeth and swallow it at once as does the common garter snake; they may crush the prey in their coils, before swallowing, as do all constrictors; or they may have poison apparatus developed, which stupefies or kills their victim immediately.

Locomotion. Solomon selects as one of the mysteries of nature, "the way of the serpent upon the rock" and surely their adaptations for locomotion are peculiar enough to warrant this distinction. They have no legs, yet they travel, climb, and swim with ease and rapidity. They accomplish these feats by means of the broad plates on their ventral surface. These plates have their free edge toward the rear, so will catch against the slightest roughness. To each plate is attached a pair of ribs which operate somewhat as legs, with each plate as a foot. To allow free motion of the ribs, the vertebræ have a very flexible ball-and-socket joint, and the whole body is provided with exceedingly strong muscles, so that a snake really travels on hundreds of muscular legs (ribs).

This is a good example of analogy, the ribs and plates performing the same function as legs, but being of entirely different origin and structure.

Poisonous Snakes. While, fortunately, there are few poisonous snakes in the United States, their adaptations are very interesting. The long front teeth of the upper jaw are either grooved or hollow fangs, movable in some snakes and fixed in others.



From the collections of the *New York Zoological Society.*

FIG. 118. The rattlesnake, a poisonous snake but also useful as an enemy of rodents.

These fangs are connected with salivary glands which, in this case, secrete the poisonous venom, and are so arranged that the act of striking, compresses the gland and forces the venom into the wound made by the fangs.

In common with most ideas about snakes, a great deal of nonsense is current regarding the frequency and deadliness of the bite of a poisonous species. To begin with, in all the United States the annual death rate from snake bite is insignificant. Second, all snake bites are not necessarily fatal. Third, unlimited whiskey is not an antidote.

The facts of the case are about as follows, summarized from two eminent authorities, Doctors Stejneger and William T. Hornaday.

Learn to recognize and avoid three snakes: rattlers, copperheads, and water moccasins. In all the United States there are but five or six poisonous types, and even the three mentioned are rare except in certain localities. The *rattlesnake* is a fair fighter, never seeks trouble, strikes only in self-defense, and usually rattles before attacking, so that, with any reasonable care, it may usually be avoided.

There are twelve kinds of rattlesnakes in the United States, most abundantly distributed in the dry regions of the Southwest, but some kinds are found in nearly all parts of the country, unless they have been killed off by man. The largest species is the diamond back which may reach a length of eight feet.

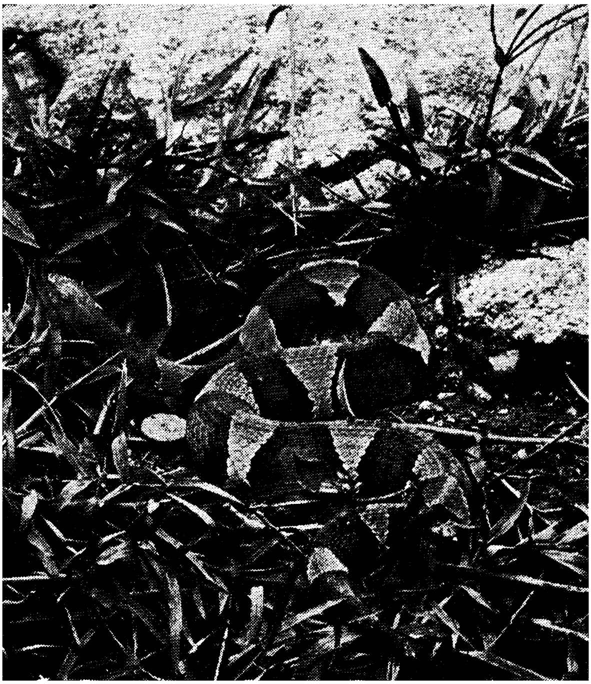
The *water moccasin* is a large dark brown snake with the head almost black above. It has a thick, heavy body, ugly head and abruptly tapering tail and may be over four feet long. It is distinctly a water snake, usually found in swamps of the South and Southwest. It strikes on slight provocation and is very venomous. There is a common harmless water snake found in the South which, unfortunately, goes by the same name, but ought not to be confused with its dangerous double.

The *copperhead* goes by other names, sometimes being called the "pilot snake" or "deaf adder," and as it attacks without warning, is actually more dangerous than the rattlers, though slightly less poisonous. It is usually found in the woods, is seldom over three feet long, and is beautifully colored with broad bands of old copper on a background resembling new copper. Any snake remotely resembling this description is to be avoided. While not abundant, the copperhead is rather widely distributed from Pennsylvania and Nebraska southward.

These three kinds of snakes belong to the group known as "pit vipers" because of a depression or pit between the eye and nostril on each side of the head. This would not do as a

safe means of recognition, as it sometimes requires rather close inspection to see it.

The harlequin snake and coral snake of the South are small, brightly colored species, and while poisonous, are so small as



Courtesy of "Nature Magazine."

FIG. 119. The copperhead, a dangerous snake.

to be of little danger. They are related to the deadly cobra of India, one of the most venomous snakes in the world.

Treatment of Snake Bites. Bites are, fortunately, generally received on the arms or legs, and are not necessarily, nor usually fatal if properly treated. Campers in snake-infested regions can obtain for five dollars or less, an outfit consisting of a hypodermic needle, chromic acid solution, permanganate

of potash, and liquid strychnine, which with the anti-venom serum, now easily obtained, constitute almost sure protection.

In case of accident, the treatment should be as follows:

1. Cut the wound to promote free bleeding.
2. Tie a ligature above the wound.
3. Use anti-venom serum if at hand.
4. Give alcoholic stimulants in frequent, *small* doses: an excess may cause death.
5. If no serum is available, inject either the chromic acid or permanganate of potassium.
6. Inject liquid strychnine (15–20 minims) every twenty minutes until spasms begin.
7. Ligature must be loosened at times to allow the circulation of enough blood to prevent mortification.
8. Summon a doctor if possible, but it is the treatment of the first hour that counts.

When you realize that only about two in over 100,000,000 persons die of snake bite in the United States each year,—that we have few kinds of venomous snakes in this country, and finally, that rational treatment is usually successful, you can see how foolish is the fear and hatred so often shown toward these really useful and handsome animals.

Turtles. The name "turtle" will be here used to include true turtles, together with the tortoises and terrapins. Tortoise is really the better name for the land species and turtle or terrapin for the aquatic forms. However we cannot go into that here; the only way to be really exact would be to use the scientific names. (See p. 184.)

Turtles form a familiar and interesting group in which adaptations for protection have been carried to such an extent that neither the rapid locomotion nor other defensive devices of the snake are necessary. The ribs are enormously widened, and joined edge to edge. They are covered, in most species, with horny plates and the under parts are similarly protected, though the extent of the armor varies with different kinds. Another curious adaptation is the horny beak which takes the place of teeth and is just as efficient in catching animal

prey, or gathering vegetable food. Most turtles are carnivorous and live on insects, larvæ, tadpoles, and fish. Some prefer water plants.

The box turtle (tortoise), found rather commonly in our woods, has the most complete protection. It can withdraw head, feet, and tail within the shell, and by means of a hinge on the ventral plate can so bend the under part of its armor, that the whole body is enclosed in the shell.

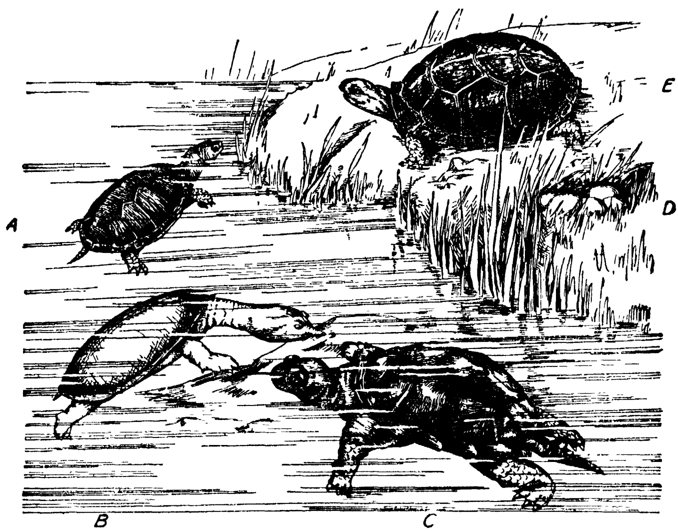


FIG. 120. Different kinds of "turtles." *A*, painted turtle; *B*, soft shelled turtle; *C*, snapping turtle; *E*, land turtle or terrapin; *D*, turtle eggs.

Among the commoner turtles, the snapping turtle represents the other extreme. Its legs and head cannot be completely withdrawn under the upper shell, and the lower plate is small, affording little protection. The snapper makes up for this by its formidable beak and long, swift-moving neck. It can "snap" with great speed, is not afraid to attack any animal, even man, and can inflict severe wounds. It lives on fish, frogs, and water fowl, and among all the turtles is probably the only one which does much harm.

Other interesting turtles are the pretty painted turtle of our fresh water ponds, and the wood turtle which is often found far from water along the roadsides and in woods. The giant tortoise, found on the Galapagos Islands, is one of the largest land turtles. It may weigh as much as three hundred pounds and sometimes reaches an age estimated at four hundred years, making it the Methuselah of the animal kingdom. The green turtle of the ocean is another giant of the group. Its shell is sometimes four feet long and it may weigh as much

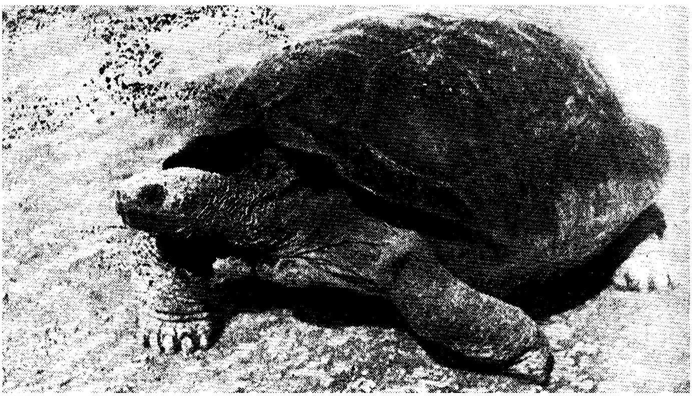


Photo by Coleman.

FIG. 121. The giant land tortoise of the Galapagos Islands. These animals may reach a length of four feet.

as five hundred pounds. It is famous as an article of food and its flesh is on sale in many markets of eastern United States.

Other food turtles are the diamond back terrapin and the red-bellied terrapin. The former is almost extinct due to unrestricted hunting, and nowadays, our "turtle soup" may contain turtle, perhaps, but probably not the famous diamond back, considered the most delicious by the epicures of earlier days.

Various forms of celluloid have largely replaced genuine "tortoise shell" but if you have any of the real article, it came

from the hawks bill turtles of the sea. They are not quite so large as the green turtles, but may yield six or eight pounds of "shell" which is often cruelly removed from the living animals.

Some turtles have no real "shell," but are provided with a tough flexible covering without plates and with few bones. These turtles, called soft-shelled turtles, are very vicious and seem able to take care of themselves, even with no shell. Both their flesh and the leathery shell are used for food.

The largest turtle of all is the leather back, a sea turtle which may reach a length of six feet and attain a weight of half a ton. Unfortunately their flesh is not good for food.

Lizards. Although there are about 1500 species of lizards known, only a few are found in the United States. They are chiefly tropical animals often of fantastic and beautiful appearance, but their peculiar appearance and habits have given them the name of being dangerous. Many curious beliefs have arisen about such lizards as the "basilisk" and the chameleon. As a matter of fact most lizards are useful, all are interesting and only one, the Gila Monster of Arizona and New Mexico, is poisonous.

They vary in size from the tiny ground lizards such as the common "swifts" or skinks, only a few inches long, to the tropical iguanas which are several feet in length, and are used for food.

The chameleon is noted for its ability to change color to match its surroundings. This is a protective adaptation and is caused by changing the relative size of pigment glands in the skin. Chameleons are sometimes brought north to be kept as "pets." This is not a wise practice as they suffer from cold, improper food, and too much handling, and often die.

The "horned toad" is well provided with horns, to be sure, but is not a toad by any means. It is a true lizard, a native of the dry plains of western United States, where its spiny skin not only protects it from enemies, but prevents evaporation of water. Their color also resembles their surroundings and they are hard to see among the sand, rocks, and spiny cactus which form their environment.

Crocodiles and Alligators. These lizard-like reptiles are the largest of the group and have always attracted attention and inspired fear. Probably many of the "dragon" legends had their foundation, if any, in descriptions of crocodiles which do resemble the alleged appearance of those fearsome monsters of the fairy tales.

Alligators are common in southern United States and we also have one species of crocodile in Florida, though most of them are Old World forms. Unlike most lizards, they are all aquatic animals, spending much time almost submerged in the water. Projecting eyes and snout enable them to float almost under water, their scaly back looking like a rough log as they await the approach of prey which is usually fish or other aquatic animals. Alligators, despite their terrifying array of teeth, are not usually dangerous to man, but some crocodiles will attack man and do much harm in Africa and India.

Crocodiles are larger than alligators, sometimes reaching a length of fifteen to twenty feet. The skin is covered with horny plates, which, although very hard, will not stop a bullet, as sometimes claimed.

Alligator skin is much prized for leather, and unless restrictions are placed on hunting them for this purpose, the species will soon be rare or extinct.

COLLATERAL READINGS

Types of Animal Life, Mivart, pp. 121–148; *Forms of Animal Life*, Rolleston, pp. 67–73; *Winners in Life's Race*, Buckley, pp. 89–122; *Animal Life*, Thompson, pp. 259–264; *Elementary Zoölogy*, Kellogg, pp. 303–326; *Textbook of Zoölogy*, Linville and Kelly, pp. 348–363; *Textbook of Zoölogy* (elements), Davenport, pp. 349–369; *Textbook of Zoölogy*, Colton, pp. 196–207; *Lessons in Zoölogy*, Needham, pp. 198–211; *Advanced Text in Zoölogy*, Shipley and McBride, pp. 457–494; *Advanced Text in Zoölogy*, Parker and Haswell, pp. 291–305; *Advanced Text in Zoölogy*, Claus and Sedgwick, pp. 208–209; *Practical Zoölogy*, Davidson, pp. 211–226; *Familiar Life of Field and Forest*, Mathews, pp. 57–80; *Talks About Animals*, pp. 155–159, 211–216; *American Natural History*, Hornaday, pp. 313–353; *Reptile Book*, Ditmars, entire; *Economic Zoölogy*, Kellogg and Doane, pp. 260–272; *Reptiles and Batrachians of New York*, Bulletin, entire; *Biology of Man and Other Organisms*, Linville, 102–111; *Practical Zoölogy*, Hegner, pp. 309–334.

SUMMARY OF CHAPTER XXX

REPTILES

1. Characteristics.

- a. No metamorphosis.
- b. No gills.
- c. Eggs internally fertilized.
- d. Scales.
- e. Claws.
- f. Young may be born alive.

2. Representatives.

- a. Turtles.
  - (1) Characteristics.
  - (2) Kinds.
- b. Lizards.
  - (1) Characteristics.
  - (2) Kinds.
- c. Crocodiles.
- d. Alligators.
- e. Snakes.
  - (1) Erroneous ideas about snakes.
    - (a) Not dirty nor dangerous, but clean and useful.
    - (b) Reason for "cold" feeling.
    - (c) Rattles per year.
    - (d) Tongue for feeling.
    - (e) Fangs.
    - (f) Hissing.
    - (g) Reason for slow death.
    - (h) "Hair snakes."
    - (i) "Hoop snakes."
  - (2) Methods of food-getting.
    - (a) Caught by teeth and swallowed (garter snake).
    - (b) Crushed before swallowing (boa constrictors).
    - (c) Venom to kill or stupefy (rattler, cobra).
  - (3) Adaptations.
    - (a) For food-getting.
      1. In-curved teeth, jaw attachment.
      2. Jaw attachment and jaw.
      3. Elastic skull and jaw.
      4. Tongue sheath.
      5. Protrusible trachea.
      6. Air sac.
      7. Elastic gullet.
      8. Strong digestive fluids.
    - (b) For locomotion.
      1. Rib attachment to ventral plates.
      2. Ventral plates (scutes).
      3. Flexible spinal column.
      4. Analogy between legs and ribs.

(4) Poisonous snakes.
  (a) Apparatus.
    1. Fangs (hollow or grooved teeth).
      a. Movable or fixed.
    2. Poison from modified salivary glands.
    3. Muscles for ejection of venom.
  (b) Kinds.
    1. Rattlesnakes (several species) (known by rattle).
    2. Copperhead (pilot or deaf adder) (known by color).
    3. Water moccasin (found in southern swamps, large).
  (c) Treatment of snake bites.
    1. Promote bleeding.
    2. Ligature above wound, if possible.
    3. Use serum or permanganate of potash or chromic acid.
    4. Stimulate with little alcohol or strychnine.

CHAPTER XXXI

BIRDS, THEIR STRUCTURE AND ADAPTATIONS

Vocabulary

Prehension, the act of grasping.
Impair, to interfere with.
Concave, curved in.
Eliminate, to excrete or throw off, as waste.
Coördinate, to make to work together.

The group of birds is one of the most familiar, useful, and interesting, of all the animal kingdom. Among the vertebrates the birds are the most highly specialized in structure, every organ being adapted for the one object, namely, flight.

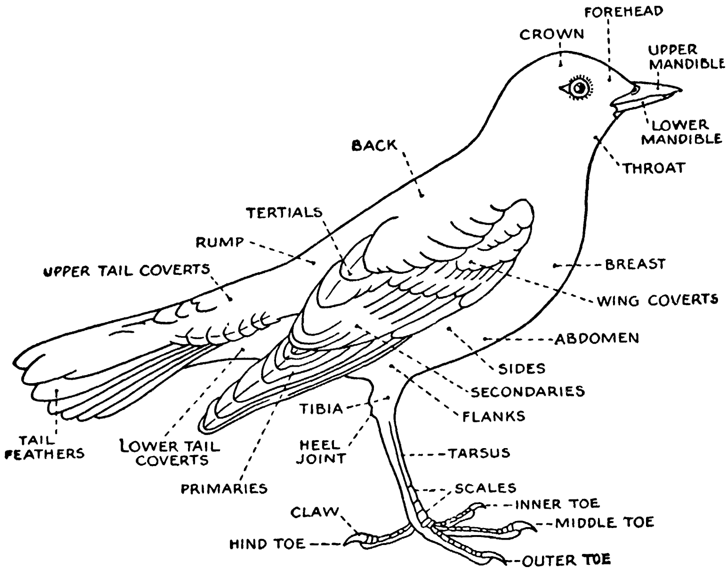
Birds are sharply distinguished from all other animals by the following points, among many others:

1. Their body is covered with feathers.
2. Their forelimbs (arms) are developed as wings, solely for locomotion and never for prehension.
3. The mouth is provided with a horny, toothless beak.
4. The body is supported on two limbs only (like man).

Adaptations for Flight. The general smooth *outline*, due to the thick covering of feathers, permits easy and swift passage through the air with little resistance. The flexible neck and legs provide for easy "fore and aft" *balance*, while the wings, being attached high above the bulk of the body, prevent danger from tipping over sidewise. *Lightness* is secured by very slender, hollow, air-filled bones, with few heavy joints; by numerous air sacs scattered through the body; by feathers for covering and locomotion; and by having teeth replaced by the light but strong beak. The chief flight adaptations, however, are the structure of the feathers and the wing. These will be discussed somewhat in detail.

Feathers. Feathers are modified forms of scales and like them develop from the skin. Some unchanged scales are

always found on the feet of birds which remind one of their relationship to reptiles. Feathers are not evenly distributed over the bird's body, but are found in certain areas between which the skin is nearly bare, though the overlapping feathers do not reveal it. There are three kinds of feathers: the soft down which retains bodily heat, the ordinary body feathers that



After Kellogg.

FIG. 122. Diagram of birds' body, showing names of external parts and regions.

give the smooth and graceful outline to the otherwise angular form, and the large quill feathers of the wing and tail.

These latter are the ones concerned in flight and consist of a broad *vane* spreading from an axis (the *rachis*) terminating in a hollow quill. The vane is made up of innumerable rays called barbs, each like a tiny feather, having projections called barbules (little barbs) which in turn are held together by interlocking hooks of microscopic size. This complicated arrangement provides a vane which is strong, light, and elastic. Furthermore, if the barbules become unhooked as when a feather

is "split" by accident, the bird merely shakes them or draws them through its beak, and the feather is whole again. This is a great advantage over a wing membrance such as is possessed by the bats which, if once injured, cannot be repaired.

The rachis is grooved and the quill hollow, both being adaptations to secure greater strength and less weight. At the base is an opening through which nourishment is supplied during its growth. The vane of the wing feathers is wider on one side of the rachis than the other. When the wing strikes against the air it tends to turn up, but rests against its neighbor and is held flat, while on the return stroke it is free to turn. The air passes through the wing as each feather partly turns on its axis ("feathering") and the wing meets less air resistance.

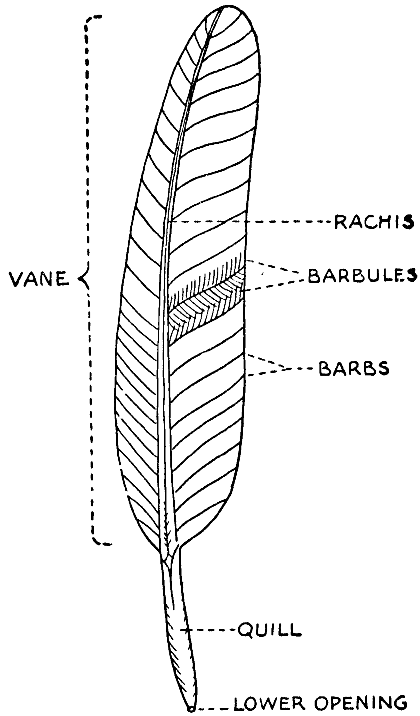


FIG. 123. Structure of a quill feather.

Uses of Feathers. The feathers provide the means of flight and aid in easy locomotion by giving the angular body a smooth outline. Moreover feathers, being one of the best heat-retaining substances, serve to keep the bird warm, even in the coldest weather, no matter how high or swift its flight. The birds' great activity necessitates high body temperature and the feather covering retains this heat and makes possible their life in the cold upper air. The feathers of most birds are oiled by a secretion taken from a gland near the tail and spread on

them by the beak. This makes them waterproof and is best shown in swimming and diving birds, which can spend hours afloat and suffer no discomfort.

Feathers have a further use in providing a colored covering which helps birds in escape from discovery by enemies because of its resemblance to their surroundings. This coloring may also be used to attract mates.

Moulting. Birds shed their feathers at least once a year, so that new ones may replace any that are lost or damaged. This is especially important in the case of wing feathers. Some species moult twice annually and may have differently colored plumage at different seasons. This change of color is sometimes used for protection and sometimes to attract mates. Wing feathers are shed in pairs and gradually, so as not to impair flight.

The Wing. The wing is almost as wonderful an organ as the human hand. Although a modified arm, it has lost all power of grasping and is adapted entirely for flight. The shoulder is strongly braced by three bones, instead of two as in man, to withstand the tremendous pull of the powerful muscles. There is the shoulder blade, the collar bone ("wish bone") and the coracoid bone extending to the sternum (breast bone). All three are devoted to supporting the wing, forming a sort of tripod arrangement, which is very strong. The upper and lower arm bones are long, strong, and slender. The wrist is lengthened as are also the fingers; only three are present, however, the other two being sacrificed for lightness. Thus we have a long, three-jointed lever, firmly attached to the shoulder with its leverage greatly increased by the feathers. The problem now consists in providing the necessary muscle to swing such an arm.

Power Required. To illustrate the difficulty involved, we may take as an example the pigeon. It weighs about a pound and has a wing spread of about two feet. This would mean that a boy or girl of ordinary weight would have to swing through the air a pair of wings each from fifty to seventy-five feet long at the rate of two hundred to five hundred strokes per minute. Try to swing your own arm at this rate for a minute, and then

imagine the power needed for a wing as long as a building lot front. If we think of keeping up this form of exercise for forty-eight hours without rest, we will have some idea of the bird's problem, and the marvelous way in which it has been solved.

Muscles, competent for this task, could not be located on the wing itself, as that would too greatly increase its weight, so we find the breast bone enormously enlarged and attached to it, muscle tissue equal in some cases to one-third the whole weight of the bird. To connect these muscles with the wing bones, a remarkable set of tendons pass over the shoulder joints like ropes over pulleys and transmit the motion to the wing, much as our fingers are closed by muscles located in the forearm.

Shape of Wing. The attachment of the feathers to the wing is no less perfectly adapted for its purpose. The longest feathers (primaries) are attached to the fingers where their leverage will be greatest. Back of them come the secondaries which brace them at the base and cover the spaces between their quills. These in turn are further supported by other rows, both above and below. The outline of the wing as a whole, with its concave under surface, thick forward edge, and thin flexible rear edge and tip, has just the form which man has recently discovered best for his aeroplane.

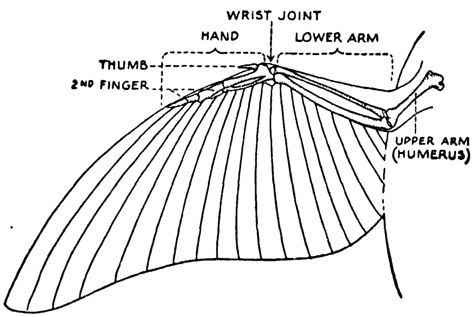


FIG. 124. Structure of bird wing. Note the greatly lengthened hand region; and the reduced number of fingers.

Flight. In ordinary flight the wing stroke resembles a horizontal figure eight—down and back, up and forward. The soaring of birds, like the hawk, where they seem to fly without any motion at all, is not understood. It may be due to slight wing motion, to balancing, or to utilization of wind currents, but so far, man has not satisfactorily explained, much less imitated it.

When man flies in the aeroplane, of which we are so proud, he flies not like the bird, with beating wings, but rather like the locust or beetle with stiff planes driven from behind. Thus far we have no engine powerful enough to swing a vibrating wing machine, large enough to carry a man in flight like a bird.

Muscles. The "white meat" of a chicken is the mass of breast muscles used in flight and the large breast bone with its projecting ridge is familiar to all of us. This ridge gives additional room to attach the powerful muscles. The outer layer of the white meat separates easily from an inside portion, this latter being very tender. The explanation is that the outer, larger, and tougher muscle was the one used in pulling the wing, down and backward in the "stroke" of flying, while the inner and more tender muscle acts by way of a tendon over the shoulder to raise the wing for the next stroke, a much easier task and one which does not toughen it.

Adaptations for Active Life. The act of flight requires more work than any other form of locomotion. This is shown by the enormous breast muscles that operate the wings, and the general activity of the bird's whole life. Great amounts of energy are required which means great food-getting and digestive ability. This, in turn, demands a remarkably complete respiratory system to provide for rapid oxidation and release of energy.

Digestion. Birds are provided with a crop for storage, a gizzard in which small stones take the place of teeth for chewing, and very powerful digestive fluids, all of which work together to care for the vast amount of fuel needed to run so powerful an engine. A young bird may eat its own weight of food every day, so the common expression to "have an appetite like a bird" is hardly a suitable comparison for a light eater.

Respiration. The respiratory organs consist of very finely cellular lungs; behind these are the air sacs which hold the reserve air and permit all the lung tissue to be used in supplying oxygen to the blood. The rate of respiration is very high and the normal temperature is from 102 to 110 degrees, which

would be fatal to man and to most other animals. Rapid oxidation means rapid production of waste matters and these are removed largely by the very highly developed lungs, there being little liquid urine eliminated by the kidneys. There are no sweat glands. Crystals of urea are excreted by the kidneys.

Not only do the lungs provide the blood with oxygen for oxidation, and also remove waste, but in addition supply the air for singing. It might be of interest to mention that the bird's song is not produced in the throat, but at the base of the trachea where the tubes from each lung join. Here is located the "song box," a very delicate and highly adjustable structure.

Circulation. To transport this large burden of digested food, oxygen, and the waste products of oxidation, there is required a large powerful heart and well-developed blood vessels. The rate of the heart beat is also rapid.

Other Adaptations. Since the bird has devoted its forelimbs (arms or wings) to flight, it must needs balance the body entirely on the other pair, a thing which is done by no other group of animals except man. As an adaptation for this, the legs are attached high on the hips, so the body hangs suspended between them. This prevents any tendency to lose balance when walking, and permits the bird to bend easily and to pick up food, which has to be done with the beak since the forelimbs cannot be used for prehension.

Man, although he can balance on two legs, falls easily and has to learn to walk, but no one ever saw a bird fall down, or have any difficulty in walking. The difference is due to the fact that the bulk of man's body is *above* the point of support at the hips, while that of the bird swings below.

Perching. The bird usually perches on a support when at rest or asleep and for this purpose has a very curious arrangement. The tendon that closes the claws passes over the leg joints, hence the more the leg is bent, the tighter the claws close up. Thus when the bird settles down on a branch to sleep, the more it relaxes and the more its legs bend, the closer

the claws grasp the perch. This and the balancing adaptations enable them to cling to a swinging twig when awake, or to a perch when asleep, with no possibility of falling.

Neck. The very flexible neck is another adaptation, especially for food-getting, since the wings cannot be used for that purpose. Not only is the bird balanced so as to bend easily but the length of the neck corresponds to that of the legs; because of this the bird can always reach the ground to pick up food.

Feet. The feet of birds differ widely in structure, depending on the particular purpose required, and are in themselves a splendid example of adaptation.

The common perching birds have three toes in front and one behind. Climbing birds, like the woodpecker, have two toes in front and two behind; swimming birds may have each toe with a separate web like the coot, or a web connecting all four, like the pelican, or only the front three, like the ducks and geese.

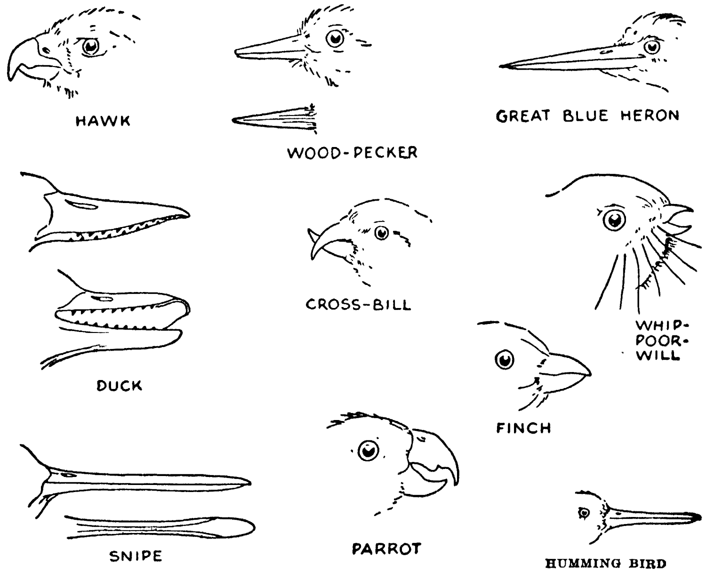
The birds of prey (hawks, owls, and eagles) have the toes provided with powerful muscles and claws which constitute their "talons" for catching food. At the other extreme are birds like the swifts, hummers, and whip-poor-wills, which have very tiny and weak feet, since they live on insects or nectar, and spend most of their time in the air.

Birds which wade along the shores in search of food have long, slender legs, like the heron, snipe, crane, and plover, while in diving birds, such as the loon and duck, the legs are so short and so far back as to make walking very awkward.

Beaks. Just as great a range of adaptation is shown by the beak of the bird. In all cases it is light, strong, and horny, thus avoiding weight. With each class of birds the beaks vary, depending on the nature of their food and the manner of catching it.

The hook-shaped, strong beak of the hawk and owl is a familiar adaptation for the birds of prey. The very sharp, chisel-shaped beak of the woodpecker enables him to drill deep into the trees for nest holes and for food. Birds like the

swifts, nighthawks, and whip-poor-wills, which catch insects on the wing, have weak but enormously wide beaks, often surrounded by hairlike feathers, making a regular trap to catch their food. The duck's wide beak with toothed edges is



After Wright and Coues.

FIG. 125. Forms of bird beaks adapted for different uses.
Hawk—powerful, short, and sharp for catching prey.
Woodpecker—chisel edged for chipping wood.
Heron—long and sharp for catching fish and frogs.
Duck—wide beak with toothed edges, to dig up mud and, by shaking the head, sift out the waste.
Cross-bill—a pair of pliers for opening cones to get the seeds.
Whip-poor-will—weak beak but wide mouth, surrounded by stiff hairs to catch insects on the wing.
Finch—the short, strong beak of a seed eater.
Snipe—slender and sensitive for probing after food in the mud; found in many shore birds.
Parrot—hooked and toothed for climbing and defense.
Humming bird—slender for sucking nectar from flowers.

provided for scooping food from the mud and straining it out between the notches when the head is shaken. The slender and sensitive beak of the snipe is used to probe in the mud for single pieces of food. Parrots use their short, hooked beak

for defense, food-getting, and for climbing. Sparrows and finches have short straight beaks for crushing seeds. The crossbill has developed a real pair of pliers for opening cones, which contain the seeds he eats. At the other extreme is the humming bird with its delicate tubular beak, able only to suck the nectar of flowers.

Nervous System and Sense Organs. To properly coördinate and control so complicated and highly adapted an organism, a well-developed brain is necessary. In birds, for the first time, the brain completely fills the skull; the cerebrum is broad and the cerebellum especially large, as is to be expected in so active an animal.

The optic lobes are also well developed but the olfactory (smell) lobes are usually small and the sense of taste is poor, since the food is swallowed without remaining in the mouth to be chewed and tasted.

The bird's eye is a very wonderful instrument, the sight being keen both at a distance and for close vision, and the change of focus is very quickly made. This is necessary in birds, because they must see clearly to pick up food at their feet, or detect an enemy at a distance, observe their prey far off, or weave a nest close at hand, and their ability along this line is unequaled by any other animal.

Their hearing is usually acute though there are no external ears, the openings being protected by a ring of feathers. Keenness of this sense is useful to escape danger and to recognize the songs and calls of their mates.

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Classification and Types: *Economic Zoölogy*, Kellogg and Doane, pp. 273–294; *Birds of Eastern North America*, Chapman, entire; *Bird Life*, Chapman, entire; *Citizen Bird*, Wright, entire; *General Zoölogy*, Linville and Kelly, pp. 374–397; *General Zoölogy*, Colton, pp. 222–245; *Types of Animal Life*, Mivart, pp. 66–95; *Little Brothers of the Air*, Miller, entire; *American Natural History*, Hornaday, pp. 171–309; *N. Y. State Museum Memoir*, Vols. I and II, entire; *American Geographic Magazine*, bird numbers, entire; *Bulletins of U. S. Department of Agriculture; Bulletins of Audubon Society; Bird Guides* (Land Birds, Water Birds), Reed, entire; *Biology of Man and Other Organisms*, Linville, 112–122; *Practical Zoölogy*, Hegner, 335–359.

SUMMARY OF CHAPTER XXXI

BIRDS

1. Characteristics.

- a. Feathers.
- b. Wings.
- c. Beak.
- d. Two feet.
- e. Egg with shell.

2. Adaptation.

- a. For flight.
  - (1) Shape of body.
    - (a) Feathers to smooth outline.
  - (2) Balance.
    - (a) Neck.
    - (b) Legs.
    - (c) Attachment of wings.
  - (3) Lightness.
    - (a) Hollow bones.
    - (b) Air sacs.
    - (c) Feathers.
    - (d) Beak.
  - (4) Feathers.
    - (a) Origin (modified scales).
    - (b) Distribution (tracts).
    - (c) Kinds.
      - 1. Down (for warmth).
      - 2. Regular feathers (for outline).
      - 3. Quill feathers (for locomotion).
    - (d) Structure.
      - 1. Vane.
        - a. Barbs.
        - b. Barbules.
        - c. Hooks.
        - d. Advantages (lightness and ease of repair).
      - 2. Rachis.
        - a. Grooved (for strength).

3. Quill.
   a. Hollow (for strength and lightness).

(e) Shape (one-sided for "feathering").

(f) Uses.
   1. Flight.
   2. Contour.
   3. Warmth.
   4. Color.
   5. To shed water.

(g) Moulting.
   1. For repair.
   2. For replacement.
   3. For color change.

(5) Wing.
   (a) Homologous to hand, not analogous.
   (b) Bones.
      1. Three shoulder bones (in tripod form).
         a. Shoulder blade (narrow).
         b. Collar bone (wish bone) (united).
         c. Coracoid (to breast bone) (special for flight).
      2. Arm bones (long and slender).
      3. Hand long.
         a. Reduced to three fingers (Why?)
   (c) Shape.
      1. Feather arrangement (Why longest feathers at end?)
      2. Concave below.
      3. Flexible rear edge and tip.

(6) Muscle power.
   (a) Muscles not on wing (Why?) (cf. human hand).
   (b) Breast muscles one-third weight.
   (c) Outer and inner layers (white meat).
   (d) Large ridge on breast bone.
   (e) Tendons and pulleys at shoulders.

b. For active life.
   (1) Need for much energy, oxidation, food, food-getting.
   (2) Digestion.
      (a) Crop (for storage).
      (b) Gizzard (for grinding in place of teeth) (Why?)
      (c) Powerful digestive fluids.
      (d) Flockwise feeding.
   (3) Respiration.
      (a) Lungs finely cellular (Why?)
      (b) Air sacs for reserve air.
      (c) Air in bones.
      (d) High rate of breathing and temperature.
      (e) Excretion via lungs.
      (f) Use of air in song.
      (g) Location of syrinx.
   (4) Circulation.

(a) Heart.
1. Four-chambered.
2. Rapid beat.
(b) Blood vessels.
1. Large (especially those to breast).

e. Other adaptations.
(1) Attachment of legs.
(a) For balance (cf. man).
(b) Ease of picking up food, since no hands present.
(2) Perching.
(a) Tendon action.
(3) Neck.
(a) Flexible and muscular (Why?)
(4) Feet and legs.

Structure of toes	Examples	Adapted for
3 front; 1 rear	Song birds	Perching
2 front; 2 rear	Woodpecker Parrot	Climbing
All webbed, separate	Coot	Swimming
All webbed, united	Pelican	Swimming
Three webbed, united	Duck, goose	Swimming
3 front; 1 rear, heavy claws	Hawk, owl, eagle	Catching prey
Small, weak	Hummer, swift	Little used
Long legs	Crane, heron	Wading
Legs short, far back	Loon, duck	Diving

(5) Beaks. (Why not teeth?)

Kinds	Examples	Adapted for
Hooked	Hawk, owl	Catching prey
Chisel shaped	Woodpecker	Drilling in trees
Wide but weak	Night-hawk Swift	Catching insects on wing
Broad and notched	Duck	Scooping and straining
Slender and sensitive	Snipe	Probing in mud
Notched and hooked	Parrot	Climbing
Short and thick	Sparrows	Seed-eating
Crossed mandibles	Crossbill	Opening cones
Slender tube	Humming bird	Sucking nectar

(6) Nervous system.
(a) Highly developed (Why?)
(b) Cerebrum, cerebellum, and optic lobes large.
(c) Taste and smell not acute (Why?)
(d) Sight keen, wide range of focus.
(e) Hearing keen for escape and recognition (song).

CHAPTER XXXII

BIRD HABITS

Vocabulary

Excavated, dug out.
Inaccessible, hard to get at.
Stringent, strict.

Feeding. As before mentioned, their intense activity requires that birds obtain large amounts of food. Almost every thing that can be eaten comes to the table of some kind of bird, certain ones eating animal food exclusively, others are strict vegetarians, while many use a mixed diet.

The method of food-getting varies with the kind of food used. Usually the beak is employed alone, and is adapted in various ways, as mentioned in the preceding chapter. Occasionally the feet assist in catching or holding food, as in hawks, owls, and others.

It is only necessary to watch any common bird, such as a robin, for a few minutes, to observe the manner of feeding, since birds require so much food that they seem to be eating nearly all the time. Robins are in general ground feeders and may be seen searching the lawn for insects and earthworms. Both sight and hearing seem to be employed in locating their quarry and a swift motion of the beak usually secures it, though an earthworm, with its tail securely anchored in its burrow, sometimes requires a lot of pulling.

Most birds drink by taking a beak full of water and tilting back the head, so that it will run down the throat. They drink a good deal, especially in hot weather, and also frequently enjoy bathing their feathers. One of the easiest ways to attract birds is to provide them with a shallow dish of water for a bird bath. It need not be an ornate or costly affair; a vessel two feet across and a few inches deep at the center, kept full of fresh water, will be patronized by the birds all summer. The

edges and bottom should be rough enough to afford safe footing and the bath should be placed where cats cannot attack its visitors.

As mentioned above, the kinds of food used vary among the different sorts of birds. Among those using animal food are large birds of prey, such as hawks and owls, which feed upon rats, rabbits, field mice, and other small animals, also upon some other birds. Then there are many whose diet is largely or entirely fish, which they catch by diving, as do the loon, grebe, pelican, and kingfisher. Some, like the vulture and buzzard, are scavengers and eat any dead animal that they can find; such birds have sight very keenly developed. Probably the largest number of birds which enjoy an animal diet live chiefly on insects which they may catch on the wing (swifts), by burrowing (woodpeckers), from the ground (robins), or on trees (warblers).

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FIG. 126. The screech owl. Valuable as destroyer of insects and mice.

Many birds live almost exclusively on seeds, doing much good by the destruction of weed seeds while others, such as blackbirds and bobolinks, do considerable damage by their preference for grain, peas, and rice. Various kinds of both wild and cultivated fruits, especially berries, are preferred by certain birds for all or part of their bill of fare, though usually the fruit-eaters have to change to an insect diet during seasons when fruit is scarce.

It sometimes happens that birds enjoy the same seeds or fruits that man raises, or they may at times rob his yard of a

FOOD USED BY SOME OF OUR COMMON BIRDS

Name of Bird	Insect Food	Vegetable Food	Rodents, etc.	Possible Harm
Quail	Potato bugs, etc., 14%	Weed seed, 63%		
Woodpeckers	Wood borers, ants, 3 to 5000 ants apiece			
Night hawk	Grasshoppers, flying ants			
King bird	Flies, bees, beetles	Wild fruits		
Phœbe	Beetles, spiders, 93%	Wild fruits		
Blue jay	Harmful insects, 19%	Nuts and acorns	Mice, fish, salamanders	Eats some corn, eggs, young birds
Crow	Grasshoppers, beetles	Corn, wild fruit	Mice	Pulls corn, eats eggs, chicks, frogs
Red-wing	Grasshoppers, weevils	Weed seed, 57%		Grain, fruit, peas, and corn
Meadow lark	Grasshoppers, etc., 73%	Weed seed, 12%		
Grackles	Insects, 35%	Grain, fruits	Mice and snails	Some fruit, grain
Junco	Beetles, caterpillars	Weed seed, 875 tons per year		
Field sparrow		Weed seed mainly		
Swallows	Flies, ants, wasps, enormous numbers			
Cedar bird	Insects, caterpillars	Wild fruit, seeds, 74%		Cherries, 5%; cultivated fruit, 13%
Wren	Insects, 98%			
Robin	Grasshoppers, 43%, caterpillars	Wild fruit, 47%		Some cultivated fruit
Bluebird	Insects, 76%	Wild berry seed		
Horned owl			Rabbits, rats, mice	
Cooper's hawk			Rabbits, birds	Chickens, grouse
Sharp shinned hawk			Mice, birds	Chickens, other birds

stray chicken, but very careful study has proven that there are but three or four birds which do more harm than good. The rest many times repay for their fruit by destruction of insects and vermin. Birds in whose favor little can be said are the Cooper's and sharp-shinned hawks, great horned owl, and English sparrow. The first three destroy poultry and useful birds, while the sparrow is driving away many valuable and attractive native birds.

Nest Building. The fact that the bird's egg requires continuous external heat for hatching is a point in which they differ from all lower forms and which necessitates the construction of some sort of nest to protect the eggs and retain heat. Next to migration, the highest development of bird instinct is shown in some of their nest construction. We must remember that they have no hands or foreclimbs to help, but merely beak and feet, and their materials are only such as they can find. Yet, when the wonderful home of an oriole or humming bird is studied, we realize that even with hands, and brain, and tools, we could not imitate them. Nests differ widely both as to materials and construction. Earth, clay, sticks, grass, hair, feathers, moss, and even strings are some of the substances used, while the structure itself may vary from a mere hole in the sand (ostrich) to the dainty nest of a vireo.

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FIG. 127. Nest and eggs of humming bird.

Excavated Nests. Water birds often lay their eggs on rocks, with only sticks enough to keep the eggs from rolling; holes in the ground serve for kingfisher and bank swallows, while owls and woodpeckers excavate homes in hollow trees.

Nests of Some Common Birds

Name	Nest in or on	Material and description
Kingfisher	Hole in bank	6 to 8 ft. deep; eggs on ground or few feathers
Woodpecker	Holes in trees	Usually cut into hollow tree through side
Crested fly catcher	Holes in trees	Bulky, of grass, etc. May use a snake skin
Robin	On branch or crotch	Bulky, of mud and straw, grass lined, heavy
Blue jay	On branches	Bulky, ragged, of twigs, leaves, rags, string, etc.
Crow	In trees	Very bulky, of sticks, cedar bark, sod, hair, etc.
Grebe	In bogs	Decayed damp plants
Red-wing blackbird	In bushes and reeds	Deep, mouth contracted, of grass and rushes
Phœbe	Under bridges or on houses or rocks	Moss, cemented with mud and lined with hair
Barn swallow	Hollow trees or eaves	Mud and straw, lined with hay or feathers
Chimney swift	Hollow trees or chimneys	Sticks glued with saliva, cup shaped
Whip-poor-will	Dead leaves	No real nest, slight depression
Quail	Underbrush	Arch of vegetation over nest made of grass
Meadow lark	Underbrush	Similar to above, but smaller
Marsh wren	On reeds in swamps	Many dummy nests, made of reeds and grass, down lined
Humming bird	On high branches	Tiny, deep nest, saddled on branch, moss covered
Oriole	Over-hanging branch of elm tree	Pendant, woven of hair, string, and grass Bottom compact, sides loose, resembles hornets' nest
Oven bird	On ground	Under arch of grass, entrance at side

Woven Nests. Very simple grass nests are made by ducks and wading birds. Among the most remarkable woven nests are the covered pendant homes of orioles and vireos, hanging from slender limbs where no thieving cat or red squirrel can come. Horsehair and plant fibers are used and so well are they selected and woven that the nest often withstands the storms of several seasons, and is repaired and used again, frequently by the same pair that built it.

Built-up Nests. Robins make a clumsy nest of clay, lined with grass and feathers, placed on the big branches where cats easily reach them. Swallows are much better masons and build clay nests on barns and cliffs, which are very strong and inaccessible. They roll the clay into pellets with the beak and build the walls a little at a time, leaving one layer to dry before adding more, lest it all collapse. The chimney swift (which is not a "swallow" at all) builds a nest of sticks held together by a sticky saliva which hardens into a strong glue. This is used in China to make a sort of edible gelatine; it is from this fact that come the stories of the "edible birds' nests" of that far-off land. These are merely some of the various types of nests. Each species of bird builds its own peculiar structure, always in the same way, of similar materials, and in the same kind of location. Yet there seems to be no way in which one generation is taught to build like its ancestors, and when we say it is due to instinct, we have not explained how they learn to construct such perfectly adapted homes.

Both the nest building and the incubation (sitting) are usually done by the female, though in some species the male helps in both processes. On the other hand the cowbird avoids either task by laying her eggs in other birds' nests, where the young cowbirds sometimes crowd out their foster brothers.

Eggs. Reproduction in birds is by means of eggs as has been the usual method in animals previously studied, but the size, structure, and care of birds' eggs place them on a higher plane of development. The development of birds' eggs requires constant warmth. This necessitates the building of a nest

and the constant care of the parent, neither of which is usually required in lower animals.

Structure. The egg consists of the actual growing point or germ spot at the upper side of the yolk, the yolk surrounded by the "white," this by a double membrane, and this in turn by the shell. The germ cell is fertilized and from it the chick develops. The yolk and white both furnish food for the developing embryo, somewhat as does the endosperm of a seed, while the membranes and shell are protective coverings, porous enough to admit air to the chick, and to allow the discharge of carbon dioxide. Fertilization takes place in the ducts leading from the ovaries. Cell division goes on for about twenty-four hours and then ceases, only to recommence in case the egg is warmed and kept at proper temperature.

As the tiny egg germ passes along the oviduct, the yolk and white are added, layer by layer; these layers sometimes separate in a hard boiled egg. The yolk is the real egg, corresponding to that of fish or frog, while the white and shell are added nourishment and protection somewhat like the jelly that coats the frog and toad eggs.

Decay of stored eggs is caused by bacteria that pass through the pores of the shell. If eggs that have no bacteria in them (*i. e.*, "fresh") are sealed air-tight by a solution of water glass, they do not decay as no bacteria can get in. If eggs are kept in cold storage, the bacteria, even though present, do not develop and the egg "keeps" for months with but little change.

The shape of most eggs is oval. In fact the word oval means "egg shaped" and is derived from the Latin word for egg, which is ovum. Oval eggs seem to pack better in a nest than would be the case if they were round, and certainly they will not roll out so easily. In many cases, birds that make deep, safe nests have eggs less oval, perhaps because they are safe from rolling out, without this adaptation.

The number of eggs varies with the amount of care that the parent birds can give the young. It is greatest in those kinds whose young receive the least attention and which try to shift for themselves early in life. This increases their chances of

destruction and makes necessary more eggs if any are to survive. In case of birds that are helpless when hatched and are fed and protected by parents, the number is lower. Common wood and field birds average about five, while game and river birds have twelve or more; on the other hand birds of prey produce one or two.

The size of the egg is greater in those species which hatch well developed, since more stored food is required to carry on the longer development. In all cases, however, they are large in comparison with eggs of other animals.

The color varies greatly and is probably protective in some cases where nests are open and exposed. On the other hand, eggs laid in burrows and deep dark nests are usually white, possibly to make them more visible.

Use. Since the egg is practically a store of food for a young animal, it provides an especially nourishing and concentrated form of human food which has been used by man for ages. Eggs require no cooking, are rich in protein and fat and are practically all digestible. The egg crop of the United States is worth over $300,000,000 per year.

Incubation. The time of "sitting" or incubation is in proportion to the size of the egg and varies from thirteen to fifteen days for small eggs, to forty or forty-five days in the case of the swan. The female usually sits, but the ostrich is an exception. Some other male birds help in the incubation. The temperature required is 105 degrees and must be kept almost constant. In birds which are helpless and have parental care, the incubation begins as soon as the first egg is laid, and the chicks hatch one after the other, but in those birds like our hens, whose chicks hatch fully feathered and able to feed themselves, all the eggs are laid before sitting begins, so that they may all hatch at one time.

Flight. The general adaptations for flight were mentioned in the previous chapter. These apply to birds in general, but as we all know, the actual manner of flight differs greatly in different birds, and there are some birds which do not fly at all.

The ostrich has wings too small to carry its heavy body, and so escapes its enemies by running, for which its powerful legs and padded feet are well adapted. They may attain a speed of 60 miles per hour. The kiwi of New Zealand and the rhea of South America are land birds which cannot fly, and the polar penguin has its wings modified into paddles to aid its webbed feet in swimming.

The typical flying birds differ greatly in their manner of flight and their skill and endurance of this method of locomotion. Observation of our common birds shows the wide contrast between the powerful, soaring flight of a hawk, and the hovering, darting motion of a humming bird.

The up and down course of a gold finch can be recognized as far as the bird can be seen; the steady flapping flight of the crow is just as characteristic. The swooping night hawk on his evening hunt for insects, the beautiful darting flight of the swallow on a similar quest, and the velvet soft passage of an owl at night, are as characteristic of the birds as their color or size.

Bird Migration. One of the most mysterious and wonderful instincts in the world is that which controls the migration of birds. The causes, methods, and means are little understood. Many birds never migrate, such as the ostrich, fish-eaters, and parrots. Crows, owls, jays, woodpeckers, and many others are practically permanent residents.

Migration may be caused by food supply, climatic changes, or may be made for breeding purposes. It is not easily understood why some species leave abundant food and warmth in the tropics to breed in the cold and barren North. Insect eaters have to migrate as winter kills their prey; water birds must leave their ponds before they freeze over; fruit eaters follow the season of their diet to some extent, but after all, this does not account for the majority of cases.

Ducks, hawks, swallows, and swifts migrate by day. Warblers, thrushes, sparrows, and some shore birds travel by night, thus gaining opportunity for day time feeding. The distances covered are enormous and could hardly be believed, were they

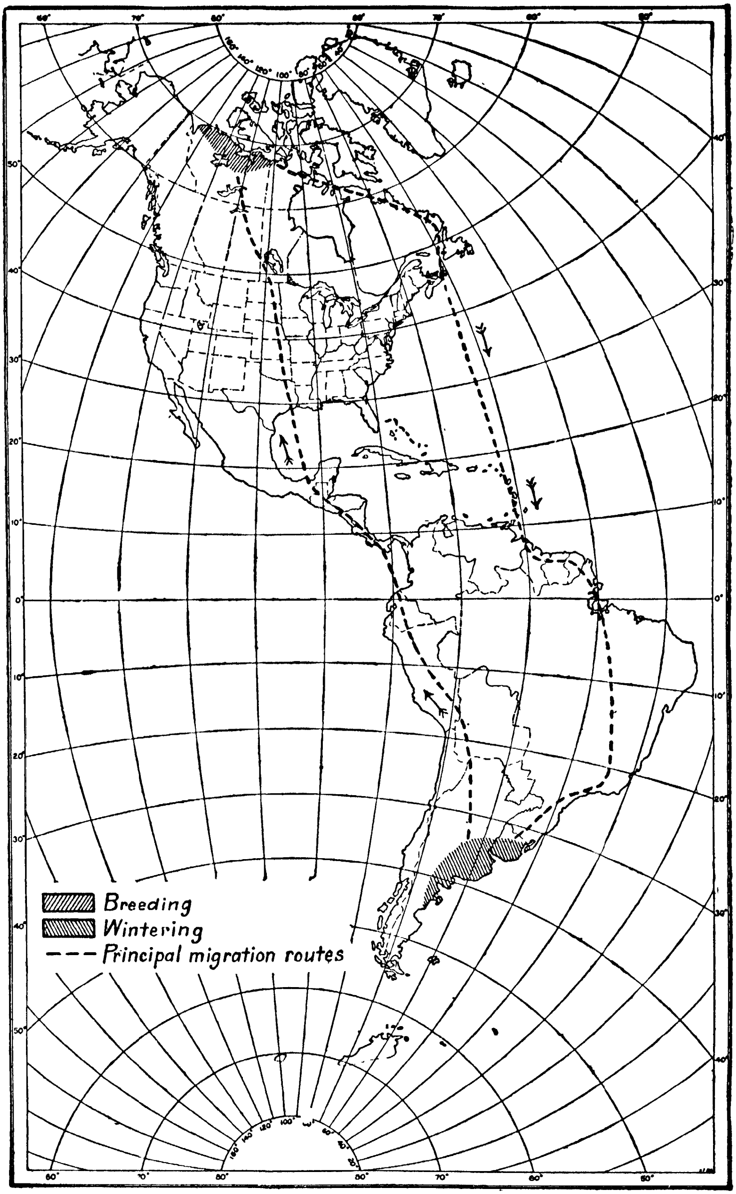

FIG. 128. Distribution and migration of the Eskimo curlew. (From Cooke; *Yearbook, U. S. Department of Agriculture*, 1914, *see* Pearse.)

not abundantly verified. Here are some examples of the start and finish of their journeys:

The bobolink travels from New York to Brazil		2500	mi.
" black poll warbler from Alaska to South America		5000	"
" night hawk	" Yukon to Argentina	7000	"
" shore birds	" Arctic regions to Patagonia	8000	"
" arctic tern	" Arctic to Antarctic circles	11000	"

This last is the champion long-distance traveller. The arctic tern makes the *round trip* in twenty weeks.

While many birds migrate slowly, feeding by the way, and averaging only twenty to thirty miles per day, there are others which are marvels of speed and endurance. Bear in mind that it is considered a record performance to drive a car from San Francisco to New York, 2500 miles, in a week and that the trains require about four days. Then look at some of these records.

The gray-cheeked thrush travels from Louisiana to Alaska in thirty days, a distance of 4000 miles. Golden plover travel from Nova Scotia to South America in forty-eight hours, a distance of 2400 miles. Over the open ocean without chance for rest, this bird uses two ounces of its fat as fuel for the whole 2400 miles. Compare this with the fuel used in the best aeroplanes, which even then have seldom travelled half this distance without stopping. The tiny humming bird has a record of 500 miles per night, across the Gulf of Mexico, and then is not tired enough to rest, but often flies on inland to make a good trip of it.

Routes. Wonderful as are birds' speed and endurance, a real mystery surrounds their knowledge of the times and routes for migration. Similar species follow the same routes year after year, some going direct over the ocean (like many water birds) some follow the West Indies across to South America; many cross the Gulf of Mexico directly over 500 to 700 miles of open water. Others follow the coasts or river valleys and may even go by one route and return by another. How do they know the way? Keen sight may help, but not over water or through

dark nights and fogs. They do not seem to follow water ways or mountain ranges in many cases. The memory and leadership of old birds, though often helpful, cannot account for migration of young by themselves to lands they have never seen. We have to assume an instinct of migration and a "sense of direction" developed to a degree that we can only imagine, and that is really no explanation at all.

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SUMMARY OF CHAPTER XXXII

BIRD HABITS

1. Foods used.

a. Animal foods.
- (1) Rats, mice, rabbits, etc. (hawks, owls, birds of prey).
- (2) Fish (loon, pelican, kingfisher).
- (3) Scavengers (vulture, buzzard).
- (4) Insects on the wing (swifts, night hawks).
- (5) Insects under bark (woodpecker).
- (6) Insects on the ground (robins).
- (7) Insects on plants (warblers, vireos).

b. Vegetable foods.
   (1) Weed seeds (sparrows, etc.).
   (2) Grains (rice) (blackbirds, bobolink).
   (3) Fruits (waxwing, blackbird).

2. Nest building.
a. Necessity for nest.
   (1) Warmth for egg.
   (2) Protection of young.
b. Kind of nest.
   (1) Excavated in earth (kingfisher, bank swallow).
   (2) Excavated in trees (woodpecker, owl).
   (3) Woven, cup-shaped (warbler).
   (4) Woven, hanging (orioles, vireos).
   (5) Built up of clay (robin, cave swallow).
   (6) Built up of sticks (chimney swift, not swallow).

3. Eggs (cf. other forms of eggs as to size, covering, fertilization).
a. Structure.
   (1) Germ spot.
      (a) Develops embryo.
   (2) Yolk.
      (a) For nourishment.
   (3) White.
      (a) For nourishment.
   (4) Membranes.
      (a) Protection.
      (b) Admit air.
      (c) Exit CO_2
   (5) Limy shell.
      (a) Protection.
      (b) Admit air.
      (c) Exit CO_2
b. Decay.
   (1) Causes.
   (2) Means of prevention.
c. Shape.
   (1) "Oval."
   (2) Reasons.
      (a) Better fitting.
      (b) Will not roll.
d. Number.
   (1) Fewer where more parental care and young helpless.
   (2) Larger where young are precocial.
   (3) Average, five.
e. Size.
   (1) Larger where chick hatches well developed.
f. Color.
   (1) Probably protective in some cases.
   (2) White in dark nests.

g. Use as food for man.
    (1) Concentrated.
    (2) Need no cooking.
    (3) All digestible.
h. Incubation.
    (1) Time.
        (a) Small eggs less time (13–15 days).
        (b) Larger, 40–50 days.
    (2) Female usually "sits."
    (3) Hatching of chicks.
        (1) In series in altricial birds.
        (2) All at once in precocial birds (Why?)

4. Migration.
a. Causes.
    (1) Food scarcity.
    (2) Climatic changes.
    (3) Breeding.
b. Methods.
    (1) Day flight (ducks, hawks, swallows, etc.).
    (2) Night flight (shore birds, warblers, thrushes).
    (3) Flockwise travel.
        (a) For protection.
        (b) For direction.

CHAPTER XXXIII

BIRD VALUE AND PROTECTION

Vocabulary

Plumage, bird's feathers as a whole.
Progenitor, ancestor or parent.
Rapacious, greedy.
Conservative, not exaggerated.

There is no group of animals to which man is more indebte than the birds, though this has only recently been appreciate Without their aid agriculture would be impossible and ou fertile fields would be reduced to a barren waste by insect or our crops crowded out by weeds, both of which are held check by our feathered helpers. Not even the dog so well d serves the title "Friend of Man."

It is estimated that insects if unchecked would destroy a vegetation in three years. Even as it is, insects do two billic dollars worth of damage each year in the United States an weeds add five hundred million dollars to this annual total. it were not for the birds this amount would be much greater.

Economic Importance

Eggs. The cash value of wild bird products is not grea enough to warrant their use. The eggs of gulls, terns, heron and ducks used to be taken in enormous numbers for food. Th has resulted in destroying or driving away the birds and now generally forbidden by law.

Game birds such as the pigeon, prairie chicken, heath hei and wood duck were formerly killed by thousands for marke Again man's rapacity brought its own punishment and he lite ally "killed the goose that laid the golden eggs." Some these birds are extinct or nearly so, and market hunting is no forbidden or regulated in most states.

Feathers. Another use of birds, now fortunately being restricted by law, is for millinery. The only plumage that may now be legally used is that from domestic birds and ostriches. This is still of much commercial importance.

Fertilizer. In some Pacific islands where millions of sea birds have roosted for centuries, vast deposits of manure, called guano, have accumulated and furnish a valuable fertilizer.

Various Uses. A curious and rather pitiful use for birds is to detect poisonous gases in mines and in warfare. Their rapid respiration and delicate nervous system make them more sensitive than man to the presence of dangerous gases. They are taken in cages into the mines or trenches where their symptoms of suffocation give warning in time for the men to take precautions.

Another very specialized use for birds, which war has greatly developed, is the carrying of messages by pigeons, carefully trained to return to their homes, when carried to the front and liberated. Often they have been able to bring back messages through shell fire where no man could live.

By no means least, is the value of birds to man as companions and pets. If the world were deprived of all bird song and color, it would be a dreary place, and even those who now overlook them, would miss their accustomed presence.

Insect Destruction. The foregoing are relatively unimportant uses of birds. It is as insect eaters that their greatest service is done. About one-half of all annual species are insects. In proportion to their size they are among the most rapacious feeders. They frequently display a preference for the plants which man raises for his food.

Birds are the chief enemies of insects. There are about thirteen thousand species of birds in the world, of which eight hundred fifty live in North America and perhaps two hundred kinds might be found in one region. On the other hand there are fifteen thousand species of insects within fifty miles of New York City, many of which are harmful to man. The fact that such hordes of insects are even partially held in check by the birds, shows the value of their services.

Nature tends to establish a balance. Man often disturbs it, to his sorrow. Native birds could completely regulate native insects, but man has introduced many insects from other countries, such as the gypsy moth and corn borer. These, not having their natural enemies to check them, multiply almost beyond the power of bird or man to control, and constitute one of our hardest problems. Without our bird allies, it would be insoluble.

An unwise bird law cost the state of Pennsylvania nearly four million dollars in a year and a half through the destruction which it permitted among useful birds. At the end of this period, the damage was so apparent that they repealed the law and appointed a state ornithologist to look after the birds. Actual experiments have been worked out with protected and unprotected bird regions so that the fact of their essential service can no longer be questioned.

The following estimate of the value of birds as insect destroyers is quoted from a letter written by W. C. Henderson, Acting Chief of the Bureau of Biological Survey.

"On a basis of numerous bird censuses it is practically certain that there are nearly four billion breeding birds in the United States each summer. A great majority of these are of migratory species, and individuals which are wholly migratory in the United States, breeding in the northern part of North America, equal in number, if they do not surpass, the population of breeding birds. Estimating the value of each bird in the destruction of insects at ten cents per year (it certainly is more) and the value of the purely migratory individuals at one-sixth of that of the breeding migratory and resident birds (since they spend about one-sixth of the year here), it is certain that without their services the bill for insect damage in the country would be more than $444,000,000 greater than it now is. This amount is practically a third of the latest estimate of the total damage by insects."

Destruction of Weed Seeds. Reference to the food table will show that weed seed constitutes a large portion of the menu for many birds.

Weeds annually damage crops in the United States to the extent of five hundred million and in addition necessitate great expense for labor in attempting to destroy them. Sparrows, juncos, quail, and similar birds destroy tons of weed seed every year. Without the aid of birds, this would also be a losing battle and cultivation of crops would be almost impossible.

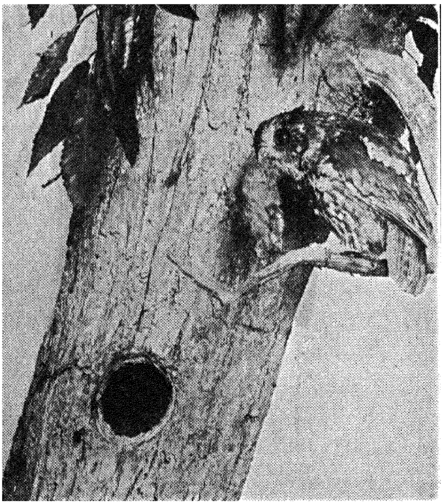
Destruction of Harmful Mammals. Hawks, owls, and other birds of prey were formerly regarded as harmful, but recent studies have proved this to be a very false idea. Only five species are harmful, six are wholly beneficial and thirty chiefly so, and seven others do about equal amounts of good and harm.

Courtesy of American Museum of Natural History.
FIG. 129. Red shouldered hawk with a mouse. Most hawks are useful in similar ways.

Their destruction of mice, squirrels, rabbits, and other harmful animals, more than pays for any poultry these birds may take. The red tailed hawk, commonly called a "hen hawk," uses harmful mammals for sixty-six per cent of its diet in which poultry only forms seven per cent. Cooper's hawk really should be called a "hen hawk" since poultry and wild birds constitute much of its fare. This hawk, together with the sharp shinned hawk, goshawk, great horned owl, and snowy owl, do more damage than good and should be destroyed. The other birds of prey should be recognized and protected as real helpers to man.

Domesticated Birds. A traveller in the forests of Farther India might be surprised to hear a familiar cackle reminding

him of the barn yard fowl back home on the farm. As a matter of fact the red jungle fowl of India is the progenitor of all our varieties of hen and we owe to some oriental poultry man of long ago the domestication of our most valuable tame bird.



Courtesy of American Museum of Natural History.
FIG. 130. Screech owl bringing home a mouse for supper.

The goose still can be found wild as the gray lag goose of the British Isles which is the probable ancestor of our domestic geese, now valued for flesh, eggs, and feathers. The beautiful mallard duck, still highly regarded as a game bird, is the ancestor of the domestic form and still can be raised in captivity and tamed. The turkey, despite its name, is a truly American bird, a native of this country and common in the woods when the Puritans landed in New England. There are three wild species in North and Central America from which our domestic varieties are derived.

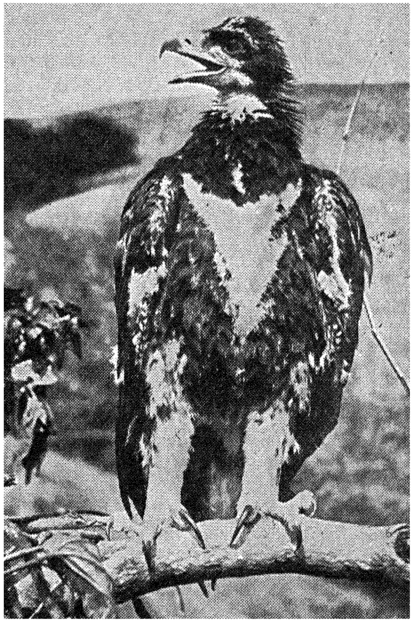
The annual value of chickens and eggs in the United States is over a billion dollars ranking well up to dairy products, which one would think of as much more important.

Harm Done by Birds. There is no other large group of animals so uniformly valuable, or with so few harmful members. Three hawks and two owls have been mentioned as killers of wild and domestic birds. To them must be added the English sparrow which drives away native birds, kills the young, and breaks up their nests, especially of bluebirds and swallows.

The starling is a similar pest in some regions. Both are

immigrants and, lacking their natural enemies, have multiplied too fast in their adopted country.

Crows do considerable harm to corn and, together with their cousins the blue jay, they destroy eggs and young of other birds. To balance this, both birds destroy many insects and it is doubtful if they ought to be killed, except in certain regions where their harm is serious.



Courtesy of Nature Magazine.

FIG. 131. The American eagle. Note the downy breast which indicates a young bird; this one is about two months old. Although our national bird, it is nearing extermination.

Bird Destruction. The advancing tide of civilization has swept away much of our bird population and has made necessary protective measures for those that remain.

The cutting of forests and clearing of underbrush have removed vast areas of bird homes. Forest fires have destroyed both the birds and their nesting places. Drainage has robbed the water bird of its marshy pool and dams have covered the shore birds' homes with water. High buildings, lighthouses, and electric wires take their toll of thousands of bird lives dashed out against them in flight.

Man is also responsible, perhaps for greater destruction, by deliberate hunting of birds for sport, food, or feathers or with the usually erroneous idea of protecting his crops. Our

domestic cat and certain introduced birds have increased the destruction of our native bird population

Due to these, and other causes, the great auk, passenger pigeon, and Labrador duck are now extinct. The wild turkey, heath hen, white egret, prairie chicken, and Carolina parrot will soon follow in their footsteps, unless prompt measures are taken to protect them.

Hunting for Food. Quail, pigeons, and prairie chickens have been slaughtered for food, literally by the ton. One hunter who kept a record admitted the destruction of 139,628 game birds during his active life. It is not strange that these birds disappear.

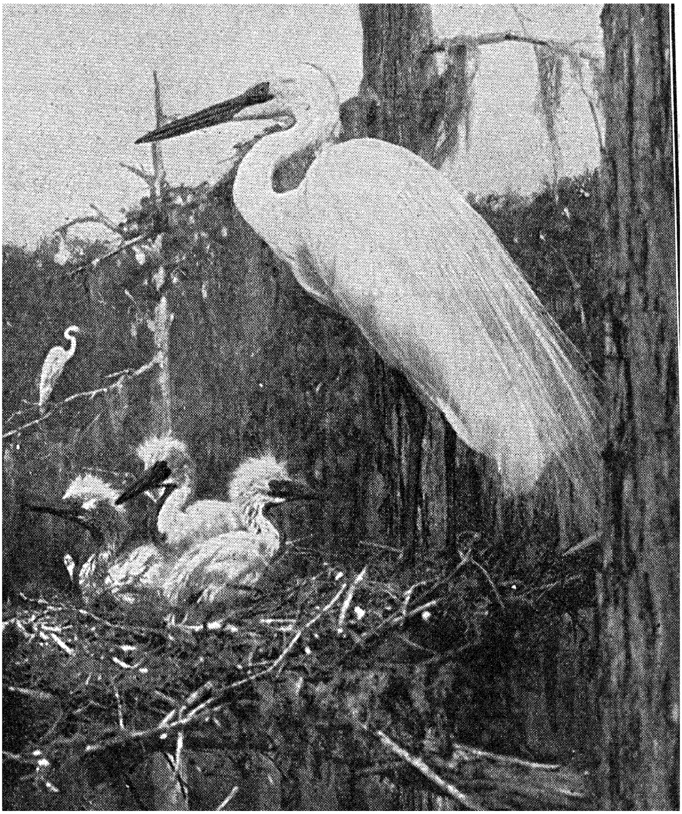
Cheap and efficient guns and the ease of covering large areas by use of automobiles has given the modern hunter great advantage. Even with restrictive laws, there were about five million hunters in the field during 1919. Half a million guns and five million cartridges is a low estimate of their annual purchases largely used for bird destruction.

Hunting for Feathers. The barbarous habit of wearing feathers has resulted in almost as great bird destruction for millinery. The white egret, found in millions in the South thirty years ago, is now rare and would be extinct but for recent protection. Their lovely plumes developed at the breeding season. Plume hunters killed them then and left the young to starve.

Before restricted by law, all sorts of small birds were killed to adorn (?) women's hats. One region in Long Island shipped seventy thousand bird skins to New York in four months; one London dealer sold four hundred thousand American bird skins and three hundred fifty thousand from India in three months. Is it any wonder that the birds decreased and insects multiplied? Happily, the worst of this slaughter is stopped. Law and public sentiment, developed by a better knowledge of the true value of birds, have put a stop to this national disgrace, but not before a great harm had been done.

Natural Enemies. Birds also have many enemies among the other animals. Cats probably do the most damage, especially

when allowed to hunt at night. Ownerless, stray cats should be killed and pet cats kept from bird hunting. A conservative estimate of this source of destruction is fifty birds per cat each year.



Courtesy of American Museum of Natural History.

FIG. 132. White egrets. The birds carry their plumes only during the nesting season; killing the parents means the slow starvation of the young.

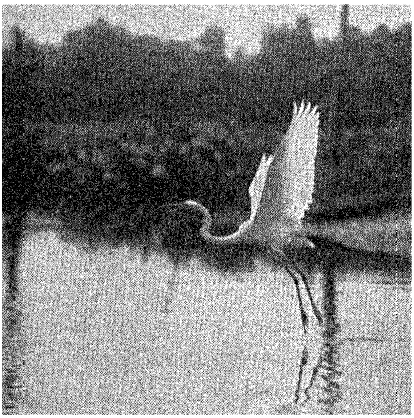
Red squirrels, rats, deer mice, and weasels take their toll of eggs and young birds and should be destroyed.

Cooper's hawk, sharp-shinned hawk, goshawk, snowy and great horned owl are destroyers of many birds. Crows and

jays destroy eggs and young. English sparrows and starlings drive away native birds.

Nearly all snakes will eat eggs or young birds but the black snake is the worst offender.

Against these natural enemies, birds could hold their own if man would not interfere. However, with the cat raised and protected by him, and foreign birds introduced by his agency, the balance is turned against the birds, even if man did not kill them himself.



© Howard Taylor Middleton.

FIG. 133. Flying egret.

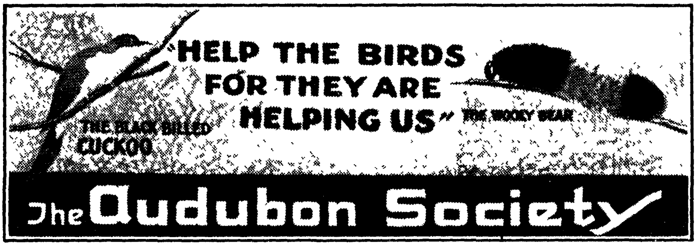
BIRD PROTECTION

1. **By Information.** The surest way to secure protection for any thing is to convince people of its value. In the case of birds many agencies are working to this end, having in view the spread of information regarding the great usefulness of birds and creating a sentiment favoring their protection.

One of the most active organizations for bird protection is the *National Association of Audubon Societies,* founded in 1902 by William Dutcher and named after John James Audubon, who was the most noted early student of American birds. The Audubon Society supplies literature regarding birds and bird habits, doing this educational work through its publications, schools, and the press. It also attends to propagation of wild birds and one of its greatest contributions has been the securing of government and private bird sanctuaries and preserves where birds may live and breed, unmolested.

The Audubon Society also uses its influence to secure the

enactment of state and federal laws for bird protection. Another agency constantly working for bird protection is the United States Department of Agriculture, through the Bureau of Biological Survey and by means of Farmers' Bulletins. This important Bureau has charge of the conservation of birds and other animals, controls the national bird reservations, ad-



Courtesy of Nature Magazine.

FIG. 134. A good use for billboards; a roadside message from near Pittsburgh, Pa.

ministers laws regarding commerce in game, and publishes many bulletins and much other information as to the distribution and value of birds and other animals.

Other Organizations helping in this work are the *American Ornithologists' Union*, the *League of American Sportsmen*, the *Agassiz Association*, and the *Society for the Prevention of Cruelty to Animals*.

Much valuable and interesting literature can be had free or at small cost by writing to the nearest representative of any of these organizations, or to your State College of Agriculture or Conservation Commission.

2. **By Laws.** As early as 1885, the Ornithologists' Union drafted a Standard Bird Law sometimes called the Audubon Law, which has been adopted in forty states. Its provisions are as follows:—

(a) It defines game and non-game birds.

(b) Forbids killing the latter at any time and provides closed seasons for game birds.

(c) The English sparrow, sharp shinned and Cooper's hawks, great horned owl, raven, and crow are not protected.

(d) It protects nests and eggs of protected birds.
(e) It forbids sale or transportation of protected birds.
(f) It permits taking of any birds or eggs for scientific purposes.
(g) Provides fine or imprisonment for violation.

In 1900 the Lacey Law was passed. As amended in 1909 it covers the following points.

(a) The Department of Agriculture is authorized to preserve, restore, and distribute game and other birds.
(b) The Secretary of Agriculture may buy and distribute such birds as seem necessary.
(c) The Secretary is also instructed to publish information as to the use and preservation of birds.
(d) Shipment of birds from states where it is illegal to kill them is forbidden.
(e) Special protection is provided for Federal bird sanctuaries.

The Federal Tariff Bill of 1913 as amended in 1919 forbids importation of feathers, skins, plumes, wings, or quills of wild birds.

Birds of Paradise, egrets, aigrettes, and ospreys are expressly forbidden. Eggs may not be imported except for game propagation.
These provisions are not to apply to ostrich feathers or eggs nor those of domestic fowls.
Stocks of the prohibited plumes, offered for sale, may be seized and given to museums or destroyed.

Of perhaps even greater importance was the Weeks-McLean Law of 1913 which is embodied in the Federal Migratory Bird Treaty Act, ratified in 1918.

This is not only a Federal Law but is combined for enforcement by treaty with Canada and Great Britain, thus giving uniform protection to migratory birds on both sides of the Canadian boundary.

The act provides (a) permanent closed season on all migratory insect-eating birds such as the thrushes, oriole, wren, chickadee, flicker, catbird, bobolink, etc.
(b) A limited closed season on migratory game birds, such as snipe, plover, waterfowl, woodcock, etc.
(c) A long closed season for wood duck and eider duck which are in danger of extermination.
(d) Provides bird refuges where no hunting may be done at all.
(e) Forbids egg collecting, except for scientific purposes.

Nearly all States have some bird laws, some very weak and others excellent: New York has the *Bayne-Blauvelt Law* which protects all birds and forbids the sale of native wild game birds, no matter where killed. Cats found at large and hunting birds may be killed in New York and foxes are also outlawed because of their damage to the ruffed grouse or partridge.

The Federal Department of Agriculture publishes a free bulletin giving the game laws of every State. More complete information as to birds and other game can be had from your own State Capitol or College of Agriculture.

In general, throughout the United States, all song birds must not be killed at all, nor may their nests or eggs be disturbed. Game birds are usually protected by a closed season during the time of nesting at least.

3. **Reservations.** Another effectual means of bird protection has been the establishment of bird sanctuaries, refuges and preserves, both by government and private action.

Such sanctuaries are areas of various extent, set apart by national, state, or local governments or by private individuals, in which no hunting is permitted. Birds and other animals soon locate the areas where they are undisturbed and flock there in amazing numbers.

At the request of the Audubon Society, President Roosevelt established Pelican Island Reservation in 1901. In 1902 the society began work in Florida for protection of the snowy heron for whose "aigrette" plumes the women's hats were demanding its destruction. Refuges were established and wardens were sent to protect the few remaining heron colonies from the plume hunter. So ruthless was the demand for millinery that in 1905 Warden Bradley was murdered while defending his reservation, and in 1908 Warden McLeod met a similar fate. With increasing protection, better laws, and more and larger sanctuaries, this beautiful bird may be saved from the fate of the passenger pigeon and Labrador duck.

These reservations were but a beginning. Government refuges have been established from Hawaii and Alaska to Porto Rico and Panama. They number over a hundred and

vary in size from Yellowstone park with an area of over 3000 square miles to Pelican Island, Florida, which was our first bird sanctuary and had an area of six acres.

Referring to Chapter LIII on Conservation you will see that these refuges are under various branches of the government. Many are along our coasts and afford protection to sea birds and waterfowl, others are inland and protect different birds and mammals. Twenty-three States and territories have reservations controlled by the Bureau of Biological Survey. The Forest Service and Bureau of Fisheries govern others. The Department of Interior, through the National Park Service, controls the largest area, much of which is held as sanctuary for both birds and mammals.

Private individuals early became interested in bird preservation and bought various tracts of land where they established sanctuaries, provided guards, and built feeding stations.

Among these may be mentioned Marsh Island, Louisiana, with an area of 77,000 acres, bought in 1912 by Mrs. Russell Sage.

The Rockefeller Foundation bought a tract of 86,000 acres in 1914 and Edward McIlhenny and Charles Ward provided another preserve of 57,000 acres, all in Louisiana. It is said that more wild waterfowl now winter in Louisiana than in any two other States.

In the more thickly populated regions of the United States it is impossible to buy large tracts but often individuals make sanctuaries of their private grounds and are always rewarded by the influx of feathered guests. The Audubon Society sometimes leases islands or lakes for bird preserves and helps in providing guards. States, towns, and cities are devoting water sheds to the purpose of bird protection, and it is to be hoped that a time may soon come when anywhere in the United States songbirds and harmless mammals may be safe, even without legal protection.

4. Methods of Attracting Birds. The ideal condition mentioned in the previous paragraph can be hastened if we all do what we can to protect and attract the birds around our homes. Summer food of insects and weed seed is usually abundant,

but planting fruiting shrubs always attracts many bird visitors that otherwise would not be seen. Elderberry, sumac, raspberry, dogwood, mountain ash, and cherry are ornamental and have the added virtue of attracting many interesting birds. Bird baths, as mentioned in Chapter XXXII, will attract many feathered bathing beauties on any hot summer day, and richly repay the small trouble of preparation.

In winter it is both easy and interesting to feed birds by fastening suet to the limbs of trees, or hanging up pork rinds and bones with meat attached. Snow can be packed down and grain scattered where it will not be covered; feeding trays can be built outside your windows or out in the woods; the feeding devices are almost as various as the foods that can be used. "Wild Bird Guests," by Baynes, and Farmer's Bulletin 621 of the Department of Agriculture give fascinating directions for this kind of bird protection.

Next to providing food, suitable shelters will attract bird neighbors. Any one can make a bird house. They need not be large nor complicated but should be adapted to the kind of bird expected. Bird houses should be put in sheltered places and at such height as to be protected from cats and other enemies. Details of construction can be had from Audubon Bulletin No. 18 or Farm Bulletin No. 609. Every yard ought to have at least one bird house and in winter one feeding device.

COLLATERAL READING

Birds in Relation to Man, Weed and Dearborn; *Game Birds, Wild Fowl, and Shorebirds*, Forbush; *Bird Craft*, Wright; *Methods of Attracting Birds*, Trafton; *National Association of Audubon Society Bulletins*, 1974 Broadway; *Bulletins* 16, *Winter Feeding;* 18, *Bird Boxes;* United States Department of Agriculture; *Farm Bulletins*, No. 609, *Bird Houses;* No. 621, *Attracting Birds*. Also bulletins of Bureau of Biological Survey: *Our Vanishing Wild Life*, Hornaday, entire; *Useful Birds and their Protection*, Forbush, entire; *Our Native Birds*, Lange, pp. 64–98; *Birds of Eastern North America*, Chapman, pp. 6–9; *Textbook*, Kellogg, pp. 370–372; *Birds that Hunt and are Hunted*, Introduction; *Birds of Field and Village*, Merriam, introduction, Chaps. XV, XXIV; *Textbook*, Davenport, pp. 311–314; *Common Birds in Relation to Agriculture*, U. S. Bulletin, entire; *How the Birds Help the Farmer*, U. S. Bulletin, entire; *Pamphlets of the Audubon Society*, etc., etc.; *Practical Zoölogy*, Hegner, pp. 361–397.

SUMMARY OF CHAPTER XXXIII

BIRD PROTECTION

1. Economic importance.

- a. Eggs.
- b. Game birds.
- c. Feathers.
- d. Fertilizers.
- e. Various uses.
- f. Destruction of insects.
- g. Destruction of weed seed.
- h. Destruction of harmful mammals.
- i. Domesticated birds.
- j. Harm done by birds.

2. Destruction.

- a. Clearing forests.
- b. Fires.
- c. Drainage and dams.
- d. Hunting by man.
    - (1) For game.
    - (2) For feathers.
- e. Cats.
- f. Natural enemies.
- g. Birds in danger of extermination.

3. Protection.

- a. By information.
    - (1) Audubon Society.
    - (2) Biological Survey.
    - (3) American Ornithologists Union.
    - (4) League of American Sportsmen.
    - (5) State conservation commissions.
    - (6) State colleges.
- b. By laws.
    - (1) Audubon Model Law, 1885.
    - (2) Lacey Law, 1900, 1909.
    - (3) Federal Tariff bill, 1913, 1919.
    - (4) Federal migratory bird treaty act, 1913, 1918.
    - (5) State laws (New York: Bayne-Blauvelt), etc.
- c. By reservations.
    - (1) National sanctuaries and refuges.
    - (2) State and local reservations.
    - (3) Private sanctuaries and parks.
- d. Methods of attracting birds.
    - (1) Fruiting shrubs and trees.
    - (2) Bird baths.
    - (3) Winter feeding.
    - (4) Bird houses.

CHAPTER XXXIV

MAMMALS

Vocabulary

Ruminant, applying to animals adapted for re-chewing their food.
Quadrupeds, four-footed animals.

The mammals constitute the highest group of the animal kingdom because in them the development of the brain, intelligence, and reason have reached the highest degree of specialization.

The birds excelled in adaptations for flight and in marvelous instincts for nest-building and migration. The communal insects have carried division of labor to a remarkable perfection, but if we compare the real intelligence of these forms with that displayed by a dog, a beaver, or a horse, not to mention man, we can see that there is no question as to the mammal's position at the top.

Mammals include man, the apes, quadrupeds, bats, seals, whales, etc., and are a very diverse group as the tabulation shows. They vary in size from the tiny harvest mouse that can climb a wheat stem, to the enormous whale, a hundred feet in length. They are found in all parts of the world except on a few small Pacific islands and are the group of animals with which man (himself a mammal) has had most to do.

The chief characteristics of this important class are as follows:

1. The young are born alive (no external eggs).
2. The young are nourished with milk.
3. The body is more or less covered with hair.
4. The cerebrum is highly developed.
5. A diaphragm (breathing muscle) is present.
6. They have two sets of teeth and fleshy lips.
7. High circulatory development, left aorta only.

General Adaptations. Mammals include about 2500 different species. Compared with the number of insects that is a small number, yet the mammals' habitat and mode of life vary so widely that they are a splendid illustration of the modification of homologous parts for different functions.

Limbs. All mammals have two pairs of limbs, usually provided with five toes; some are modified for flight (bats), some for swimming (seals, whales), some for rapid land locomotion (horse, deer), some for climbing (squirrel), or for burrowing (mole), for attack and defense (cat, tiger), for jumping (kangaroo), or for prehension (apes, man).

Teeth. In the same way the teeth may vary in structure and use, there being usually four kinds present, the incisors, canines, premolars, and molars. In some animals they are adapted for tearing prey (tiger, lion), some for gnawing (rat, beaver), some for grinding vegetable foods (horse, cow). All are of similar origin and are merely different forms of the same organs.

Body Covering. The body covering also varies greatly. The hair of the dog or horse, the wool of the sheep, the quills of the porcupine and the scales of the armadillo, are all of similar origin. Claws, hoofs and nails, horns, bristles, manes and tails are also developed from epidermal structures.

Special Adaptations. Mammals live in widely different environments which necessitate a great variety of special adaptations. Most of them live on the ground, but some inhabit the water either permanently like the whale and porpoise, or partly like the seal and walrus. The bats are excellent flyers and the so-called "flying squirrels" can sail some distances in their flying leaps.

Monkeys, sloths, and squirrels live almost entirely in trees. Moles pass nearly all their life under ground and prairie dogs, woodchucks, and ground squirrels are great burrowers also.

Naturally these varying habitats have resulted in a wide range of special adaptation. For air locomotion the bat has enormously lengthened fingers between which is stretched a thin membrane making an efficient wing. The flying squirrel

has a fold of skin between front and hind legs which, while not permitting real flight, acts as a parachute for its long sailing leaps.

At the opposite extreme is the mole. Its eyes are poorly developed; it has no external ears; but its powerful, backward turned front legs are wonderful tunneling machines. Moles have been known to dig at the rate of one foot in three minutes. In another case a mole dug over sixty feet in twenty-four hours.

The whale's aquatic adaptations include a pair of front legs developed as broad flat paddles, without distinct fingers, and an enormous tail, flattened horizontally, forming a powerful caudal fin. The hind limbs are lacking and the body is usually covered with a thick layer of fat called "blubber" which protects the whale from the cold of the water by retaining its bodily heat.

The giraffe, whose food is chiefly obtained from tall trees, has developed his famous neck for the purpose. Though having only seven neck vertebræ, the same number of neck vertebræ (seven) as man, the giraffe can raise his head a good deal higher, but has an awkward time reaching down to drink.

The elephant's proboscis or "trunk" is another curious adaptation for prehension. It seems to be a greatly enlarged nose with a delicate finger-like projection between the nostrils. With this wonderful organ the elephant can lift tremendous weights, defend himself against his enemies, or pick a tiny bit of food from the hand of a child.

Marsupials. The opossum which is found in our southern States and the kangaroo of Australia belong to a group of mammals called marsupials or pouched animals. The females of this peculiar group have a pocket or pouch on the ventral side in which they carry their young. The offspring are born much less developed and more helpless than is the case in most mammals and need this added means of protection.

While on the subject of peculiar mammals, the duckbill certainly should be mentioned. This anomalous creature lays eggs like a bird, but after they hatch nourishes the young with milk like a true mammal. Furthermore, the duckbill has

webbed feet and a horny bill, like a duck and a thick coat of water-proof hair like that of a beaver. You are not likely to encounter this curious animal except in museums, for its home is in Australia, Tasmania, and New Guinea.

Four Important Orders. The mammals of North America represent ten orders out of twelve, the two remaining orders

FIG. 135. The duckbill, an egg laying mammal.

being found in Australia or the tropics. From this number we shall study only four, the rodents, ungulates, carnivora, and primates.

The Rodents (gnawers) include many of our commonest animals, the rabbits, porcupines, guinea-pigs, chipmunks, squirrels, beavers, rats, mice, and woodchucks. All these forms have teeth especially adapted for gnawing: the front teeth (incisors) are chisel shaped, strong, and provided with a continuously growing root, so that they replace themselves as fast as they wear off. Also the front edge is harder than the rear edge, so that they are self-sharpening since the cutting edge is always worn thin. These tooth adaptations together with strong jaws and powerful jaw muscles fit the rodents for their well-known occupation of gnawing their way through life.

The Ungulates (hoofed animals) include some of our commonest domestic animals, such as the horse, pig, cow, sheep, and goat. Among its wild members are the deer, antelope, tapir, rhinoceros, hippopotamus, giraffe, camel, zebra, etc. All of these most of us have seen in circuses and zoölogical gardens. These animals live on vegetable foods and have back teeth (molars) fitted for grinding. Most of them have a side-wise jaw motion which also aids in this process. Their feet are encased in hoofs, and the limbs are never used for prehension, being adapted only

for swift locomotion. There are never more than four toes in use and frequently fewer are developed.

The Ungulates are divided into two groups:

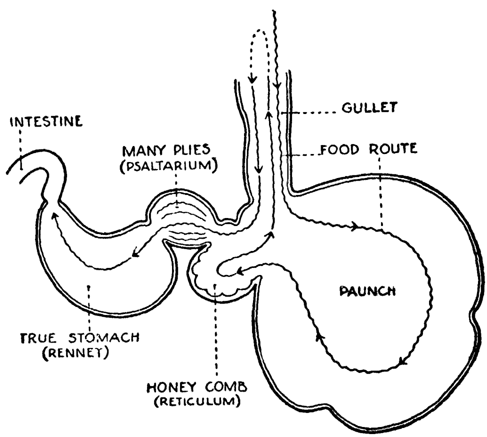
1. *Odd toed* in which the weight is borne on one toe though others may be present. They include the horse, rhinoceros, and tapir.

2. *Even toed* in which the third and fourth toes bear the weight, though two others are usually present.

These even-toed ungulates are again divided into two groups called

1. The non-ruminants (pig, hippopotamus).
2. The ruminants (cow, sheep, deer, etc.).

The ruminants are so called from their habit of chewing their food as a "cud." A cow, for example, first compresses its food into a ball, swallows it into the first of the divisions of its four-chambered stomach where it is stored. Later it is forced back into the mouth, chewed thoroughly and swallowed again, but into another stomach chamber, where the processes of digestion are completed. The advantage of this peculiar arrangement is that much food can be hastily eaten and stored, to be chewed later. This, for an animal which feeds in flocks, on bulky vegetable food is of great importance, since it can get its share in haste and chew it at leisure. The ungulates include most of our domestic animals. From them we obtain the bulk of our animal food and clothing, leather, horn, and other products



After Wiederscheim.

FIG. 136. Diagram showing course of food in the stomach of a ruminant.

and among them we find nearly all our beasts of burden. It would be almost impossible for man to exist without this important group of animals.

The Carnivora (flesh eaters) are very highly specialized in structure for the pursuit of prey, and in fact, live largely upon the ungulates whose adaptations have been along the line of keen senses and swiftness to escape this very danger. The carnivora have large, interlocking canine teeth, shear cutting molars, a very strong jaw hinge, and enormous muscles attached to ridges on the skull. Their skeleton is light and slender, the jaw short and strong, and the feet usually provided with claws. These claws, in the cat family, can be withdrawn into sheaths, which keeps them sharp and also permits a noiseless approach upon their prey.

On the other hand, the dog family cannot withdraw the claws which are therefore blunt and not used for prehension, but for swiftness of chase, which is characteristic of their manner of hunting. Their keenness of sight and smell have been especially adapted for their manner of life.

The carnivora include two divisions: (1) the aquatic forms (seal, sea lion, walrus) in which the limbs are short and web-footed; (2) the land forms with long limbs and separate toes. These land forms are divided into three groups, according to the manner of walking:

1. Those walking *flat* on the foot (bear, raccoon).
2. Those walking on the *toes only* (dog, wolf, fox, hyena, cat, tiger, lion, leopard, etc.).
3. Those walking *partly* on the toes (martin, mink, weasel, otter, sable, skunk, etc.).

It will be noticed that, except for the dog and cat, none of the carnivora are domestic animals, and few of them are used as food. On the other hand, most of our valuable furs are produced by them.

The Primates. This group includes the highest of the mammals, and comprises the monkeys, gorilla, chimpanzee, orang-utan, gibbon, marmoset, and lemur, as well as man himself.

Their structural adaptations do not compare with those found

in many other orders, but the greater brain development and intelligence places the primates at the head of the classification.

This brings up again the fact that brain development is the only way in which man may hope to excel. He belongs to what is called a "generalized order" of animals; that is, he is not structurally adapted for any particular thing, such as flight, speed, strength, swimming, etc., his only claim to distinction being along the line of intellectual development.

There is nothing that man can do, *if unaided by his intelligence*, which many other animals cannot do much better; but when this intelligence is at hand to direct him, there is no other animal that can compete with him.

Structurally, man resembles the higher apes very closely. Almost every detail of their anatomy is similar—skeleton, muscles, teeth, position of eyes, structure of the hand, and even motions and facial expressions. There are, however, certain structural differences such as the more erect position, shorter arms, larger and better-balanced skull, higher forehead, smaller canine teeth, and his inability to use the big toe like a thumb for grasping.

These differences are utterly unimportant when compared with the one great feature, the human brain. The brain of all the primates is large but man's is one-third larger than the chimpanzee's which most nearly approaches it in size.

Man has learned the use of tools, devised a spoken and written language, found a means of controlling fire, and developed mental faculties and social habits that place him in a position far above the highest apes.

It is curious to note how three factors have contributed to man's development. The erect attitude left the fore limbs free from use in locomotion and permitted their development into the most wonderful organ of prehension in the world, the hand, which is man's one point of high structural adaptation.

It is difficult to say whether the brain taught the hand, or the hand helped develop the brain, but it is certain that these three factors, erect position, hand, and brain, have been the essential ones in man's development.

There is more *structural* difference between the lowest primate (lemur) and the chimpanzee or gorilla, than there is between these higher apes and man. Also there is a greater difference between the earliest type of savage man and the highest type of civilized man than there is between the savage and the ape.

Results of Erect Posture. As a consequence of his erect posture, man's hands are left free for use in grasping things. However, nature does not give something for nothing, and man has to pay for his upright position by certain disadvantages. In the first place, since only one pair of limbs are used in locomotion, he must balance upon two feet instead of four, and has the center of weight high above the point of support. This necessitates the long and difficult process of "learning to walk" which other animals do not experience.

Placing the weight vertically on the hips instead of at right angles to them, renders man more liable to hip, spinal, and foot diseases and deformities. The internal organs rest one upon another in a vertical pile instead of lying side by side, producing a tendency to pressure or displacement. When sick or tired we instinctively lie down to relieve this strain.

The arteries of the arm-pit, neck, and groin are now exposed toward the front, whereas in quadrupeds they face downward and are protected. In man, the trachea and appendix open upward, instead of forward, giving opportunity for the entrance of irritating substances.

All these difficulties, which are the price of our erect posture, are more than repaid by the advantage of the human hand and the mental and social development which it has made possible.

It rests with the intelligence of man to overcome the natural difficulties of his structure by especial attention to correct posture, position of spinal column, and support for the arches of the feet. The strain on the internal organs can be met by training the abdominal muscles to support their extra burden, and by proper exercise and breathing. All this is but a small price to pay for the human hand.

Relationship. Contrary to the ideas of some ill-informed people, no scientist has ever claimed that man is "descended

from" an ape or any similar form, neither is there any "missing link" to be discovered. On the other hand, scientists *do* agree that both man and the apes are descended from a common ancestor from which both lines have developed. This accounts for the very great similarity in structure. In the same way, we resemble our cousins though we are not descended *from* them, but are related by way of a common ancestor, or grandparent.

Aside from man, the primates include:

1. The gorilla, the largest of the apes, a native of Africa. It is erect, does not climb trees, and resembles man closely in structure, though much stronger.

2. The chimpanzee, also found in Africa. Though smaller than man, it resembles him more closely than the gorilla, in brain, face, hands, and ears.

3. The orang-utan, found in the East Indies, which also resembles man in brain structure and skeleton.

4. The Old World monkeys and baboons (Asia-Africa), which have narrow noses and non-prehensile tails.

5. The New World monkey (South America), with wide flat noses and prehensile tails.

6. Marmosets (Mexico, Brazil), lemurs (Madagascar), small forms, much less like man in structure.

Life Functions. As we end the study of the different types of plants and animals it is well to remember that from the simplest one-celled plant to the complex body of a mammal they all perform the life functions of food getting, digestion, assimilation, respiration, excretion, and reproduction.

To perform these processes, they are adapted by structure in vastly different ways. It is one of the wonders of nature to see how these essential functions are carried on by such different creatures and in such different environments. It all goes back to the fundamental idea that all living things are alive because of their protoplasm, and that protoplasm performs the same essential life processes, whether in the amœba or the whale.

Classification of Mammals

Order	Characteristics	Representatives
Primates	High mental development, man-like	Man, apes
Carnivora	Flesh eaters	
Aquatic	Limbs modified to flippers	Seal, walrus
Land	Walk on clawed toes	Cat, dog, lion, wolf
	Walk on flat foot	Bear, raccoon
Ungulates	Hoofed, vegetarians	
Odd toed	One or three toes mostly used	Tapir, horse, rhinoceros
Even toed	Two toes mostly used, four present	
	Non-ruminant	Pig, hippopotamus
	Ruminant	Cow, deer, sheep
Proboscidea	Tusks from incisors, trunk	Elephants
Sirenia	Aquatic, conspicuous neck	Sea-cows
Cetacea	Aquatic, no neck, fin-like limbs	Whale, porpoise, dolphin
Chiroptera	Wing membrane on four fingers	Bats
Insectivora	Burrowing insect eaters	Mole, shrew
Rodents	Gnawers, sharp incisors	Rat, rabbit, beaver
Edentates	Teeth few or none	Sloth, armadillo
Marsupials	Abdominal pouch for young	Opossum, kangaroo
Monotremes	Have beak, lay eggs	Australian duck-bill

COLLATERAL READING

Mammals

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Carnivora

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Rodents

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Ungulates

Winners in Life's Race, Buckley, pp. 256–279; *American Natural History*, Hornaday, Chap. VIII; *Riverside Natural History*, pp. 233–352; *American Animals*, Stone and Cram, pp. 28–70; *Life of American Animals*, Ingersoll, pp. 231–385.

Primates

The Life of Animals, Ingersoll, pp. 7–57; *Riverside Natural History*, pp. 480–500; *American Natural History*, Hornaday, Chap. II; *Animal Life*, Thompson, pp. 340–350; *Types of Animal Life*, Mivart, pp. 1–35; *Winners in Life's Race*, Buckley, pp. 240–255, 333–355.

SUMMARY OF CHAPTER XXXIV

MAMMALS

1. Characteristics.

a. Living young, egg matures internally
b. Young nourished with milk.
c. Hair.
d. Fleshy lips.
e. High cerebrum.
f. Diaphragm.
g. Two sets teeth.
h. Well developed circulation.
i. Left aorta.

2. Modifications of limbs (two pairs, five-toed).

a. For swimming (whale, seal).
b. For flight (bats).
c. For land locomotion (horse, deer).
d. For climbing (squirrel).
e. For burrowing (mole).
f. For fighting (cat, tiger, etc.).
g. For jumping (kangaroo).
h. For prehension (man).

3. Modifications of teeth (incisors, canines, pre-molars, and molars).

a. For catching prey (lion, tiger, cat).
b. For gnawing (beaver, rat, mouse).
c. For grinding (horse, cow).
d. For tusks (elephant).

4. Modifications of body covering.

a. Hair (dog, horse, man).
b. Wool (sheep).
c. Quills (hedgehog, porcupine).
d. Scales (armadillo).
e. Claws.
f. Hoofs.
g. Bristles.
h. Tails.
i. Manes.

5. Special adaptations.

6. Four important orders.

a. Rodents.
  (1) Representatives.
  (2) Adaptations of teeth.
    (a) Chisel shape, self-sharpening incisors.
    (b) Strong, powerful jaws and muscles.
    (c) Continuous growth (Why?)
    (d) No canines.

b. Ungulates (specialized for escape).
  (1) Characteristics.
    (a) Hoofed.
    (b) Vegetable food.
    (c) Large size.
    (d) Limbs for locomotion *only*.
    (e) Not more than four toes.
  (2) Classification.
    (a) Odd-toed (horse, rhinoceros, tapir).
    (b) Even-toed.
      1. Non-ruminant (pig, hippopotamus).
      2. Ruminant.
        a. Hollow, permanent horns (cow, bison, sheep, goat).
        b. Solid, shed horns (deer, elk, moose).
        c. Characteristics of ruminant stomach.
        d. Reason for ruminant habit.
  (3) Value to man.
    (a) Food (meat and milk, with all related products).
    (b) Wool, leather, horn, etc.
    (c) Transportation (horse, ox, camel, mule, llama, etc.).

c. Carnivora (specialized for pursuit).
  (1) Characteristics.
    (a) Small incisors.
    (b) Interlocking canines.
    (c) Shear molars.
    (d) Strong jaws, jaw muscles, and hinge.
    (e) Light, strong body.
    (f) Keen senses.
    (g) Claws.
  (2) Classification.
    (a) Aquatic forms (short limbs, webbed toes) (seal, walrus, etc.).
    (b) Land forms (long limbs, separate toes).
      1. Plantigrade (bear, raccoon).
      2. Intermediate (mink, weasel, otter, skunk).
      3. Digitigrade, claws not retractile (dog, wolf, fox).
      4. Digitigrade, claws retractile (cat, lion, tiger, etc.)
    (c) Value to man.
      1. Few valuable for food.
      2. Many valuable for furs.
      3. Aid in chase.
      4. Enemies.

d. Primates.
  (1) Representatives.
    (a) Gorilla.
    (b) Chimpanzee.
    (c) Orang-utan.
    (d) Monkeys
    (e) Gibbons
    (f) Lemurs.
    (g) Man.

(2) Characteristics.
  (a) Generalized structure (meaning).
  (b) Highly developed brain.
(3) Ways in which man resembles other primates.
  (a) Skeleton.
  (b) Muscles.
  (c) Teeth.
  (d) Eyes.
  (e) Hand.
  (f) Habits.
(4) Ways in which man differs from other primates.
  (a) Erect position.
  (b) Shorter arms.
  (c) Balanced head.
  (d) Forehead.
  (e) Smaller canines.
  (f) Non-opposible great toe.
  (g) Brain and intelligence.
    1. Tool-using.
    2. Fire control.
    3. Language.
    4. Social and moral development.
    5. Mind.
    6. Reason.
(5) Factors in man's development.
  (a) Erect attitude and its consequences.
  (b) Hand free for prehension.
  (c) Brain development with results listed under (4)(g).
(6) Relationship of man and other primates via a common ancestry, not by "missing links."

(See Hornaday for pictures of all mammals, especially primates.)

CHAPTER XXXV

THE DEVELOPMENT OF MAN

Vocabulary

Vestigial organs, traces of organs formerly better developed.
Fossil, remains of former plants or animals, embedded in rocks.
Evolution, gradual development, from simple to complex.

With an egotism which is entirely unwarranted, we are accustomed to speak of "man and animals" whereas we ought to say "man and *other* animals," for certainly man is an animal just as truly as the beast of the field.

By referring to the characteristics given in preceding chapters, man's place in the zoölogical scale will be seen to be as follows:

Kingdom: animal.
Branch: vertebrate.
Class: mammals.
Order: primates.

The Idea of Evolution. As soon as man became intelligent enough to make comparisons between himself and other animals, the resemblances became apparent and led to the idea that some relationship must exist with lower forms. Two thousand years ago the Greeks discussed this fact and advanced various theories to account for it.

Very gradually, information accumulated, and the idea of relationship developed into the theory that not only man but all living things, both plant and animal, are not only related, but actually descended from common ancestors. This is called the theory of descent, or *evolution*.

Evidences of Evolution. 1. *Vestigial Organs.* Not only do all animals resemble each other in general ways, but many forms possess organs which are of no use to them, but are developed in other groups for important functions.

For example, in the foot of the horse there are unused bones which in other animals support separate toes. The ostrich has small wings like those of other birds, but it cannot use them for flight. The boa constrictor has remnants of a hip girdle though it does not develop legs to use it.

In man there are about seventy such structures, well developed in other animals but reduced in size and function in his body, like remains of the scaffolding of construction left in a completed building and showing thereby the process of its development. Among these may be mentioned the appendix which in the rodents is the largest part of the intestine, while in man it is reduced to a small and apparently useless vestige. Similarly we have small canine teeth, but do not develop them to tear food like the dog; we have an inturned ear tip and muscles to *move* the ear, but we do not "prick up our ears" like a horse.

The list might be greatly extended, but the point is this,—if animals and plants are not developed from common ancestors, why then do they have these resemblances in structure?

2. *Embryological Resemblances.* In the study of the development of the embryos of all animals, it is found that the higher forms pass through stages resembling lower types, as they develop.

The first stage is the single fertilized egg cell. This develops by similar steps, into (*a*) a solid mass of cells, (*b*) a hollow sphere of cells, (*c*) an infolded tubular form, and then up through more and more specialized structures to the adult, whatever it may be. The early forms of many vertebrate embryos are so similar that dog, cat, rabbit, or man cannot easily be distinguished until well started toward adult form.

By watching embryonic development of the vertebrates we can observe modifications of various structures, such as the gill arches, which are present in all the early stages. These gradually develop true gills in the fish, but become modified and reduced in the higher forms, their rudiments appearing in man as parts of the inner ear, lower jaw, and throat cartilages. Certainly, if animals were not related, they would not repeat the structure of lower types as they develop into their final form.

3. *Homologous Organs.* In both plants and animals we find parts, evidently of similar origin and structure, developed for very different purposes.

a. Leaves are modified into petals or thorns.

b. Roots act as organs for climbing or storage.

c. Hoofs, nails, and claws are all of similar origin.

d. Scales, feathers, and hair are all modified forms of the same epidermal structures.

e. The various appendages of crayfish and its relatives are evidently of similar structure, but modified to perform many functions.

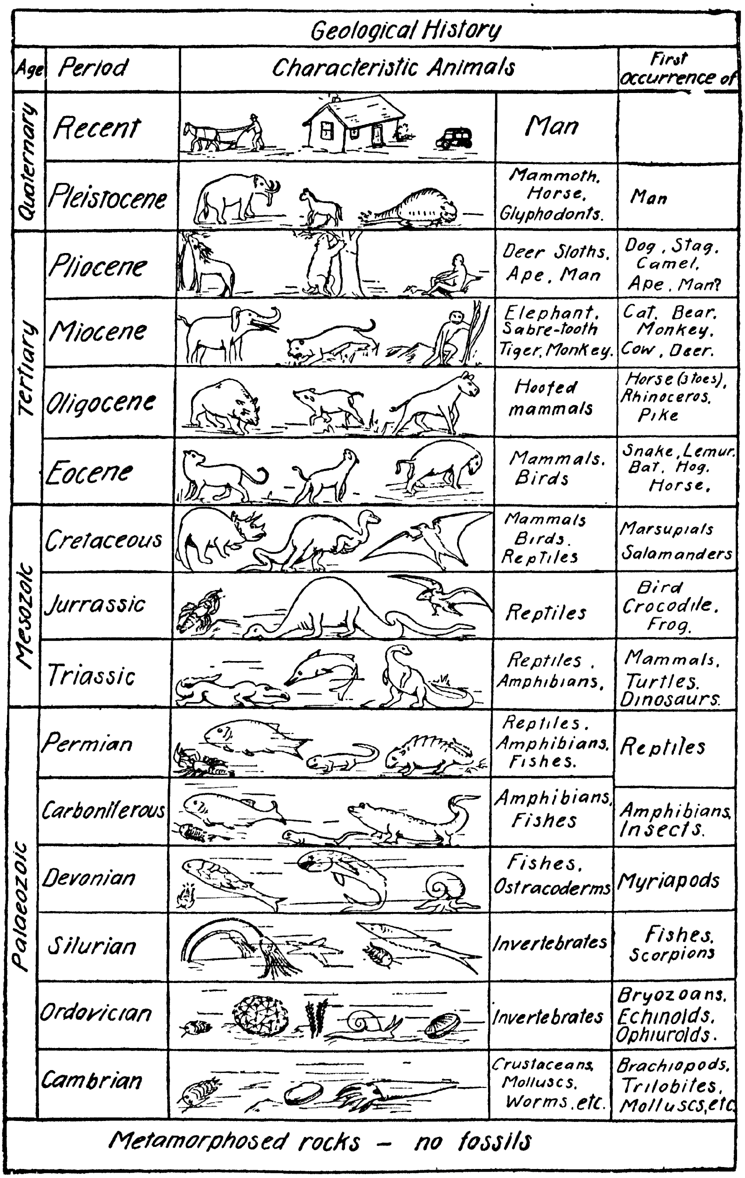
Surely this modification of similar parts for different uses would not be found if there were no relationship between the different forms.

4. *Geological Evidence.* Although the fossil remains are necessarily incomplete, still there have been found many series showing gradual development from primitive to present forms. This is notably true of the horse whose ancestors have been traced in fossil skeletons back to a small five-toed form unlike any living representatives. Also in the case of birds and reptiles, remains have been discovered, showing plainly their descent from a common ancestor.

5. *Domesticated Animals and Plants.* We are continually witnessing the development of different forms of plants and animals in our methods of breeding, in which there is no question of relationship of the new form to the old.

Our many kinds of dog are descendants from the domesticated wolf; the different breeds of hogs from the wild boar; fowls, pigeons, sheep, and cattle, with their numerous breeds and races, have been developed purposely by man, from very different ancestors.

From masses of such evidence, laboriously collected, all scientists are agreed that all living things are related, the closeness being indicated by the degree of similarity. They also agree that descent has not been in a continuous straight line, like the steps upward in a ladder, but that relationship is through common ancestors.



From Pearse.

FIG. 137. Chart showing development of different forms of animal life during the various geologic periods.

We have certain "family resemblances" to our cousins but we are not descended *from* them; rather, we resemble them because of our common ancestors (*grandparents*), who contributed to the inherited characteristics both of ourselves and them.

Proof of the *fact* of descent and evolution is only half of the problem; it remains to be shown *how* nature has brought about the great modifications which have resulted in producing the innumerable forms of living things which inhabit the globe.

COLLATERAL READING

Primer of Evolution, Clodd, Chaps. IX–X; *Origin of Species*, Darwin, Chaps. 14–15; *Descent of Man*, Darwin, Chaps. 1–7; *The Whence and Whither of Man*, Tyler, pp. 1–112; *Applied Biology*, Bigelow, pp. 561–573; *Ascent of Man*, Drummond, pp. 59–98; *Animal Life*, Thompson, pp. 273–281.

SUMMARY OF CHAPTER XXXV

DEVELOPMENT OF MAN

1. **Relation of man to other animals.**
   a. Classification (look up characteristics of each group).

2. **Evolution.**
   a. The idea of evolution.
   b. Evidences of evolution.
      (1) Vestigial organs.
         (a) Toe bones of horse.
         (b) Wing of ostrich.
         (c) Hip bones in boa.
         (d) Appendix, canines, etc., in man.
      (2) Embryological resemblances.
         (a) Beginning with one-celled egg.
         (b) Similar early stages.
         (c) Modifications of organs.
      (3) Homologous organs.
      (4) Fossil remains.
      (5) Changes due to domestication and breeding.

CHAPTER XXXVI

THE METHOD OF EVOLUTION

Vocabulary

Isolation, separation.
Contemporary, one who lives at the same time.
Divergence, separation of lines of descent.
Predecessor, one who comes before.

Proof of the *fact* of similarity between the various forms of living things, and of their very evident relationship, still leaves a more difficult question to be answered. *How* did this descent and modification take place, by what means has nature developed one form from another?

The idea of evolution of living forms from previous simpler ones had been in existence for centuries, but the first serious attempt to explain the *means* by which the new forms evolved, was made by Lamarck in 1809. He advanced the view that new species arose by inheriting the results of use or disuse of organs. For example, the giraffe, by constantly reaching for the leaves of trees, developed its neck, and the offspring increasingly inherited the characteristic until a new species was formed.

The time was not ripe for acceptance of Lamarck's ideas; moreover, his theory was not in accordance with facts and was forgotten for fifty years.

Darwin's Theory of Natural Selection. The date, 1859, marks an epoch in biological thought and should never be forgotten. In that year Charles Darwin, an English scientist, published his *Origin of Species by Natural Selection* and established the theory of evolution on a firm basis.

This theory is the corner stone of all recent science and the foundation of all modern thought. It is not confined to biology alone, but has influenced almost every branch of science. In its broader features it is accepted by every biologist, although there are many details still to be worked out.

Following is an outline of the chief factors assigned by Darwin to account for the development of new species from common ancestry.

1. Over-production of individuals.
2. Struggle for existence.
3. Variation among individuals.
4. Survival of the fittest.
5. Inheritance of favorable characteristics.
6. New forms better adapted to survive are thus "naturally selected" as new species.

Darwin spent over twenty years of strenuous toil and study, accumulating facts upon which to base his theory. Many able men have since devoted their lives to the same end, but we can here only briefly review the argument, following the outline given above.

Over-Production. A fern plant may produce fifty million spores per year. If all matured they would completely cover North America the second year. A mustard plant produces 730,000 seeds annually, which if all matured, would occupy two thousand times all the land surface of the earth, in two years. The common dandelion would accomplish the same in about ten years.

The English sparrow lays six eggs at a time and breeds four times a year; if all survived there would be no room for any other birds in the course of a decade. The codfish produces over a million eggs per year; if all survived this would fill the Atlantic solidly with fish, in about five years.

Most amazing of all is the rapidity of reproduction in bacteria and protozoa. One of the latter, if it reproduced unchecked, would make a solid mass of these microscopic animals as large as the sun, in thirty-eight days.

Struggle for Existence. We know there is no such actual increase; in fact the number of individuals of a species changes but little. In other words, only a very small minority of these countless hosts reaches maturity. All cannot obtain either space or food to live. Thus it is evident that only those best fitted for their surroundings will survive, and the less fit will perish in the struggle.

Variation. It is a well-known fact that no two individuals of any plant or animal are exactly alike; slight variations in structure occur in all. This furnishes the material for nature to use in her selection, and those forms, whose variations tend to adapt them best to their environment, will survive while others perish.

Survival of the Fittest. This expression was first used by another noted English scientist, Herbert Spencer, and almost explains itself. If among the thousands of dandelion seeds produced, some have better dispersal devices, these will scatter to better soil, be less crowded, and so will survive, while those having poorer adaptations will perish by over-crowding. In so severe a struggle where only a few out of millions may hope to live, very slight variations in speed, or sense, or protection may turn the scale in favor of the better-fitted individual. Any unfavorable variations would surely be wiped out.

Inheritance. It is common knowledge that in general, the offspring resemble the parents. If the parents have reached maturity because of special fitness, those of their descendants which most inherit the favorable variation will in turn be automatically selected by nature to continue the race.

New and Better Adapted Species. A continuation of this process of natural selection will in time produce such differences in structure and habit that the resulting forms must be regarded as new species, genera, and finally higher groups. This process is aided when the developing species are separated by distance, mountain ranges, bodies of water, or climatic differences, so that they do not lose their favorable variations by inter-breeding. This is the theory of geographic isolation which was developed by Alfred Russell Wallace, another English contemporary of Mr. Darwin.

Conclusions from the Theory. 1. *Cause of Adaptations.* It will be seen that natural selection is constantly tending to fit the individual more closely to its environment and thus accounts for the marvelous adaptations of structure which we always find in all living things.

2. *Relationship of all Forms.* Carrying the theory to its logi-

cal conclusion it follows that all the species now on earth, or which have lived there in the past, are descended from a few primitive original forms. The further back the variation began, the greater will be the difference between the present forms, and the more distant will be their relationship. Those more closely allied have separated from a common ancestor in more recent times.

3. *"Tree" Lines of Descent.* Evidently our idea of the lines of relationship and descent must be expressed in the figure of a tree whose main branches separated from the parent trunk early in development and whose topmost twigs represent the present living forms. These will be similar or different, depending on how far back the divergence began.

4. *Classification.* Evolution provides for a natural method of classification, now universally used, in which relationship and descent are shown by the groups in which individuals are placed.

Thus members of a species are more closely related than those of a genus or order. A class includes forms which began to diverge further back than the members of a family. When we speak of any forms as "belonging to the same order" or genus, we are really expressing not only their likeness in structure, but the reason for it, namely, relationship and descent from common ancestry.

5. *The Key to other Biologic Puzzles.* Evolution accounts for many facts otherwise unexplained. It tells us why we find fossil remains of simpler animals in older rocks, and of more highly specialized forms in later formations. It accounts for the facts of embryology mentioned in the previous chapter, such as the occurrence of primitive structures in the embryos of higher forms, which disappear before maturity. It explains the peculiarities of geographic distribution of animals and plants, in accordance with what we know of past and present relations of land and sea areas.

Natural selection does not seem to account for all the facts of evolution. Apparently several other factors have entered into the development and adaptation of living things. Other

theories have been advanced which help to explain certain things which Darwin's natural selection does not fully cover.

Neither Darwin nor any of his successors claims to completely explain all the methods of development by which evolution goes on. Each new discovery or theory supplements the others. The fact of relationship, descent, and evolution is unchanged. Theories like natural selection and others, seek to explain the fact.

Some Things that Evolution does Not Teach. 1. It does not teach that living or extinct forms can be arranged in a straight line of descent, each descended from its predecessor.

2. It does not teach that "man is descended from a monkey."

3. It does not teach that God can be left out of the scheme of Creation. Much opposition was made to Darwin's work on this score, by people who purposely or through ignorance, misinterpreted his conclusions. While we cannot go into the argument here, rest assured that in the minds of the greatest scientists and philosophers there is no conflict between the conclusions of Science and Religion.

To quote Davenport "The Creator is still at work, and not only the forces of Nature, but man himself, work with God in still further improving the earth and the living things which it supports."

There is nothing in science which is opposed to a belief in God and religion. Those who think so are mistaken either in their science, or their theology or both. Huxley was a contemporary of Darwin and one of the most eminent biologists, note his opinion:

"Science seems to me to teach in the highest and strongest manner the great truth which is embodied in the Christian conception of entire surrender to the will of God. Sit down before the fact as a little child, be prepared to give up every preconceived notion, follow humbly wherever and to whatever abysses Nature leads, or you shall learn nothing. I have only begun to learn content and peace of mind since I have resolved at all risks to do this."

Major W. W. Keen, M. D., whose professional training

gives him a different point of view from that of Huxley, says, "With the passing years I am more and more impressed with the wonderful mechanism of Nature, which to me bespeaks God."

COLLATERAL READING

Origin of Species, Darwin; *Descent of Man*, Darwin; *Primer of Evolution*, Clodd, entire; *Evolution*, Thompson and Geddes, entire; *Story of Primitive Man*, Clodd, entire; *Evolution*, Coulter, entire; *Ascent of Man*, Drummond, pp. 1–98; *Whence and Whither of Man*, Tyler, pp. 1–112; *Winners in Life's Race*, Buckley, pp. 333–353; *Elementary Text*, Linville and Kelly, pp. 101–115; *Animal Studies*, Jordan, Kellogg and Heath, pp. 281–289; *Elements of Zoölogy*, Davenport, Chap. 21; article on "Evolution" by Huxley in Encyclopedia Britannica.

SUMMARY OF CHAPTER XXXVI

EVOLUTION

1. Evolution idea very old.

2. Lamarck's theory of the inheritance of acquired characteristics.

3. The theory of natural selection.
- a. Charles Darwin, *Origin of Species by Natural Selection* (1859).
- b. Chief factors in development of new species from common ancestry.
  - (1) Over-production.
  - (2) Struggle for existence.
  - (3) Variation.
  - (4) Survival of the fittest
  - (5) Inheritance.
  - (6) Origin of better adapted forms.
- c. Some conclusions.
  - (1) Accounts for adaptations.
  - (2) Indicates relationship of all forms.
  - (3) The "tree" line of descent.
  - (4) Present system of classification.
  - (5) Accounts for fossil series.
  - (6) Accounts for embryo repetition.
  - (7) Accounts for geographic distribution.

4. Some things evolution does not teach.
- a. The "ladder" line of descent.
- b. The man-monkey descent.
- c. That evolution leaves God out.

Note. Darwin did not originate the *evolutionary idea* at all, as many seem to think; that was a very old belief. What he did was to prove that natural selection was a *means* by which evolution was brought about. There are doubtless other forces assisting natural selection in carrying on this development, some of which are fairly well understood.

CHAPTER XXXVII

THE DEVELOPMENT OF CIVILIZED MAN

Vocabulary

Anthropology, the study of the development of man.
Acquisition, something obtained.
Degenerate, less developed than formerly.

We have been studying the development of living things and man's relation to them, which brings us to another even more fascinating branch of biology, the development of man himself, a science called *Anthropology.*

We naturally think of man's development in terms of recorded history, but we must remember that writing is a very recent art and man's actual written records go back relatively but a little into the far past from which we are still emerging. Greek writings take us back about one thousand years B.C., Chinese, Egyptian, and Arab records may possibly date as early as 3000 B. C., but civilization was far older, and man, as a more or less human animal, much older still. Monuments and inscriptions may push back the boundary by vague information covering perhaps ten thousand years, though there is much dispute, and the data are uncertain.

Still further back amid the mists of human history we draw conclusions from bones and stone implements, showing that man existed as early as the glacial period, and was contemporary with the cave bear, mammoth, and aurochs, all now extinct. One ventures with diffidence to set a time in years for the date of these remote ancestors of ours, but apparently human animals, erect, large-brained, using weapons and tools, possessing the power of speech, and perhaps the use of fire, existed one hundred thousand years ago.

Primitive man apparently had a much smaller brain capacity than his modern descendants, a lower forehead, sloping brow,

heavy jaws, and receding chin. Still he was obviously human and, even then, intellectually far superior to the other Primates.

His earliest home must have been in relatively warm climates where nature provided food and shelter for her children too ignorant to obtain them for themselves. His food was fruit and nuts and such animals as he could capture, unarmed, and eat uncooked. This restricted his flesh foods mainly to clams and oysters, to which the enormous shell deposits still

From Weltall u. Menschheit.

FIG. 138. Remains of the Neanderthal man, in the Provincial Museum of Bonn.

bear testimony in many places in central Europe. Evidently man soon devised weapons, clubs, and spears perhaps, and later bows and arrows. Then he became a wandering hunter having no fixed home and changing his abode whenever game became scarce in any one locality.

With a widespread scarcity of game came the necessity of taming and raising food animals. Thus we have the herdsman wandering with his flocks from place to place, as pasturage and food were exhausted. Domestication of animals probably began with taming the wolf to aid him in the hunt, but the real progress was made when tame cattle, sheep, and goats, partly took the place of wilder game.

A wonderful advance was made when man hit upon the idea of cultivating food plants for his flocks and himself. This permitted a fixed habitation and for the first time, a real "home life" had a chance to develop, with all that it means in comfort and social progress. Doubtless the house was but a cave or tree shelter, but when man settled to remain in one place, to cultivate and gather his simple crops, community life and society had their earliest beginnings.

Man's development is usually classified by the implements he had learned to use.

1. *Primitive Man.* Without weapons, tools, or fire.
2. *Old Stone Age.* Stone weapons and tools, probably used fire.
   Contemporary with mammoth and cave bear.
3. *New Stone Age.* Used polished stone implements.
   Perhaps made crude pottery.
   Erected stone monuments, buried the dead.
   A period of many wars and migrations.
4. *Age of Metals.*

(a) Copper and gold first used because found pure in nature; could be shaped by hammering and did not have to be melted.

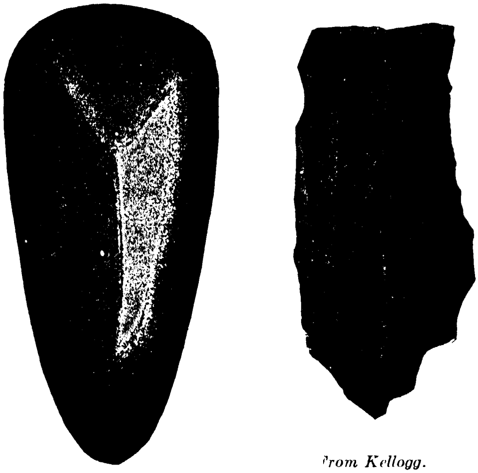
(b) Bronze, an alloy of melted copper and tin which made excellent implements and did not require great heat to melt.

(c) Iron, required skillful smelting and tempering, needing much higher temperature. Best metal for all uses. Brings us down to modern times.

The period of written history extends back at most, only into the bronze age so we can see how comparatively recent has been our modern development, and how slow was man's progress in his earlier stages.

With our modern civilization has come a complete change in the manner of life. While we would not relish going back to the life of the cave dweller, still we pay a penalty for our safer and easier methods of living. Primitive man, if he survived

at all, was necessarily a hardy, outdoor animal, eating hard foods, having a sturdy and little protected body, and literally "earning his bread by the sweat of his brow." Now we have so learned to control our environment that we live quiet, safe, indoor lives, protect our tender bodies with houses and clothes, and provide ourselves with soft and delicate cooked foods. On the other hand, we have developed our brain and nervous system so that it has to take over the work previously done by



From Kellogg.

FIG. 139. At right, a carved flint from Denmark, of the Old Stone Age; at left, a polished stone axe head from Ireland, of the New Stone Age.

muscle and brawn. Hence we are overworking our latest acquisition, our intelligence, at the expense of our bodies.

Is it any wonder then that we now have fat and flabby muscles, weak lungs, delicate skin, and degenerate teeth, combined with overworked nerves? If we are to develop to its highest efficiency the wonderful mind which the Creator has given us, we have to make special effort to keep our bodies strong, even though physical strength is no longer the one essential in the struggle for existence.

To this end modern civilization is attempting, by healthful living conditions, by education in biology and hygiene, and by systematic exercise, to maintain as healthy a body as that of our

ancestor with the stone hatchet, combined with all the marvelous abilities and achievements of the civilized mind.

We do not have to depend wholly upon the evidence of human remains to get an idea of how our ancient ancestors lived. Some Australian and African races are still almost in the stage of primitive man. Some central African tribes have no houses but sleep in what are practically nests; they hunt with stone

From Kellogg.

FIG. 140. Drawing of mammoth on piece of mammoth tusk. From the Cave of the Madeleine in Southwest France. The drawing was made by prehistoric man of the early Post-Glacial times. One-third size of original.

clubs, do not know the use of even the bow and arrow, cultivate no crops, and eat human flesh. Certain natives of Patagonia are still living in the Stone Age so far as their culture is concerned. New Caledonia furnishes examples of man but little further advanced, and some tribes of Ceylon and Australia are living in even more primitive stages of development. Still, low as this culture may be, it is yet wholly unapproached or resembled by the life of the lower animals.

Anthropologists classify the human species in different ways, but are generally agreed upon four, or perhaps five races, distinguished about as in the table on page 375.

Race	Habitat	Characteristics	Culture
Malay	Pacific islands Australia New Guinea	Dark skin Straight or wavy hair Fairly developed bodies	Lowest stage, some lack fire Language very primitive Rapidly disappearing
Ethiopian	Central Africa	Black skin and eyes Woolly hair Full jaws and long skull	Negrillo dwarfs almost as low as Australians No homes, or crops Use bows, cannibals Others much higher, negroes
American	Whole western hemisphere	Brown skin Straight black hair	Very high civilization in ancient Peru and Mexico Fine stone builders. Worked in gold and copper Had crops and domestic animals Patagonians now lowest type
Mongolian	China, Japan, India	Yellow skin Coarse black hair Flat nose Oblique eyes Very numerous	Ancient civilization very high. Developed all world religions except Christianity Invented written language
Caucasian	Western Asia and Europe Now widespread Not from the Caucasus	White skin Fine hair Regular features	Highest modern civilization as found in all white races

COLLATERAL READING

Primer of Evolution, Clodd, Chap. XI; *Story of Primitive Man*, Clodd, entire; *Story of Creation*, Clodd, entire; *Whence and Whither of Man*, Tyler, pp. 211–308; *Winners in Life's Race*, Buckley, pp. 333–353; *Animal Life*, Thompson, pp. 320–350; *Man Before Metals*, Joly, entire; *Anthropology*, Tyler, entire; *The Next Generation*, Jewett, pp. 153–161.

SUMMARY OF CHAPTER XXXVII

THE DEVELOPMENT OF CIVILIZED MAN

1. Records of ancient man.
- a. Written history.
- b. Monuments and inscriptions.
- c. Stone implements and remains.
- d. Human bones.

2. Characteristics of primitive man.
- a. Brain larger than other animals.
- b. Brain smaller than present man.
- c. Low forehead and sloping brow.
- d. Heavy jaw and receding chin.

3. Stages of development in occupation.
- a. Primitive man.
  - (1) Without weapons or fire.
- b. Hunter.
  - (1) Using spear and bow and arrow.
  - (2) Able to control fire.
- c. Herdsman.
  - (1) Wandering for food supplies.
  - (2) Domestication of animals.
- d. Cultivator of the soil.
  - (1) Permanent home.
  - (2) Crops stored for future.

4. Stages of development in implements used.
- a. Primitive man without implements.
- b. Old Stone Age.
- c. New Stone Age.
- d. Age of Metals.
  - (1) Copper.
  - (2) Bronze.
  - (3) Iron.

5. Results of present higher mental development.
- a. Body less strong and hardy.
- b. Brain greatly developed and may be overworked.

6. Races of modern man (See tabulation in text.)

CHAPTER XXXVIII

THE GENERAL STRUCTURE OF THE HUMAN BODY

Vocabulary

Cranial, pertaining to the skull or head.
Extensor, a kind of muscles which extend or straighten a limb.
Flexor, a kind of muscles which bend a limb.

If we have an automobile, we are particular to learn how it works, and how to care for it so that it will last long and run well. We select the gasoline and oil with care and when it is out of order we employ a skilled mechanic to make repairs.

If we take such care of a car which we can replace for a comparatively small sum, how much more ought we to learn to care for our bodies on which our health and comfort depend and which cannot be replaced at any price.

Yet it is a fact that we treat our own organism as we would not think of treating our car. We overstrain its parts, we give it improper food, we deny it sufficient rest, and seldom have it overhauled by an expert. Even when we are sick, instead of getting competent medical advice, we resort to patent medicine or amateur treatment. If our bodies were not so marvelously constructed, they would not function even as well as they do and even so, a perfectly sound healthy body is a rare possession.

Before we can intelligently care for our body, we must know how it works (functions) and before function can be understood, some knowledge of structure is essential.

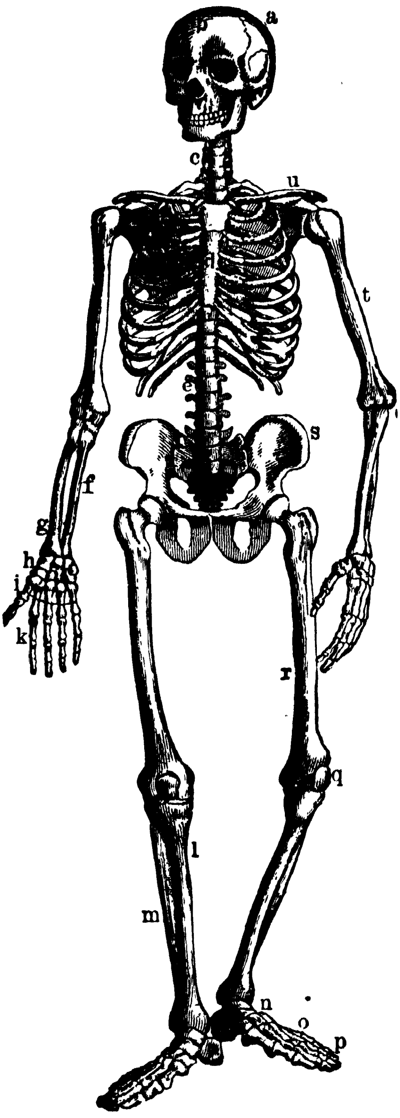
Body Regions. We already know the general body regions, head, neck, trunk, and limbs (arms and legs). We may also have heard of the three body cavities, known as the cranial, thoracic, and abdominal cavities.

The cranial cavity, protected by the skull, contains the brain; the thoracic cavity, partly enclosed by the ribs and

spinal column, contains the lungs, heart, food pipe, and many large blood and lymph tubes. A muscular partition, the diaphragm, separates the thoracic from the abdominal cavity, which occupies the lower part of the trunk and contains the stomach, intestines, and digestive glands as well as the kidneys and other organs.

Skeleton. The body is supported and protected by the bony skeleton. Bone is a peculiar and interesting tissue. We say "dry as a bone" but a living bone is far from dry, either actually or as a subject for study.

Many of the invertebrates had skeletons, but these were external and composed of material



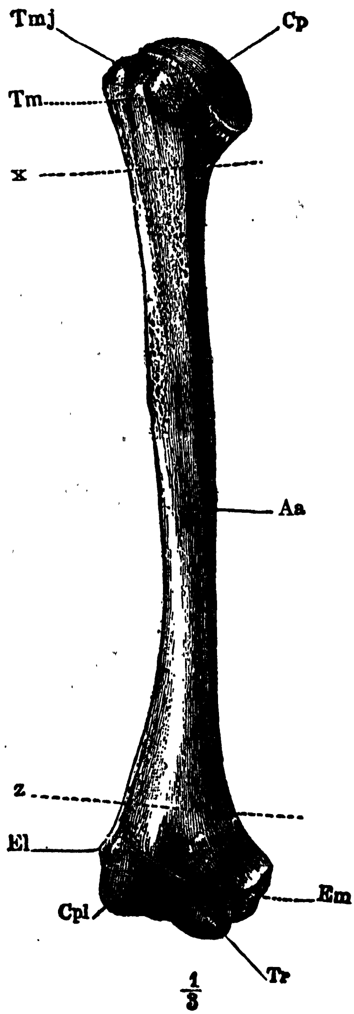
From Martin.

Fig. 141. The human skeleton. a, b, bones of the skull; c, neck vertebræ; d, breast bone; e, vertebræ of the lower back; f, ulna; g, radius; h, carpals; i, meta-carpals; k, phalanges; l, tibia; m, fibula; n, tarsals; o, meta-tarsals; p, phalanges (toes); q, knee-cap; r, femur; s, pelvis; t, humerus; u, collar bone.

different from the bone of the vertebrates' internal framework. They often secured protection at the expense of free motion as in clams and snails, or at a sacrifice of continuous growth, as in crustacea. In man and other vertebrates the internal skeleton provides for sufficient protection while permitting growth and motion unrestricted.

Composition of Bone. In some primitive vertebrates the skeleton is composed of cartilage, but in the higher forms this is partly replaced with phosphate and carbonate of calcium. In human bone about two-thirds of the weight is composed of these mineral substances. The amount of cartilage in the bones of children is greater than in adults, hence they do not break so easily, and if broken, grow together much more quickly. In a child many bones are separate which later grow together. This is the case in the skull, hip girdle, and breast bones.

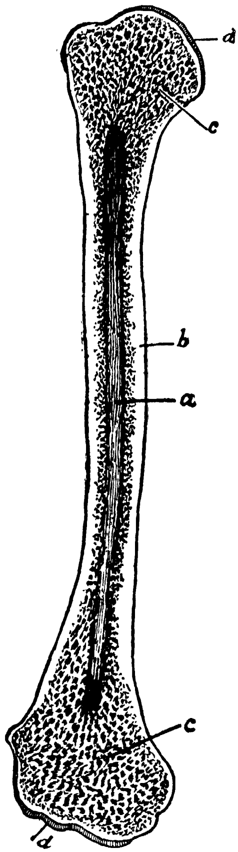
This greater flexibility permits the bones of the young to be rather easily forced out of shape by faulty shoes,



From Martin.

FIG. 142. External structure of a long bone (humerus). Cp, rounded surface for joint at shoulder; Tr, Cpl, rounded surfaces for joint at elbow; Tmj, Tm, El, Em, projections for attachment of muscles; Aa (x–z) the shaft of the bone.

clothing, or posture. This should be remembered especially in regard to the care of the feet and posture of the body.



From Martin.

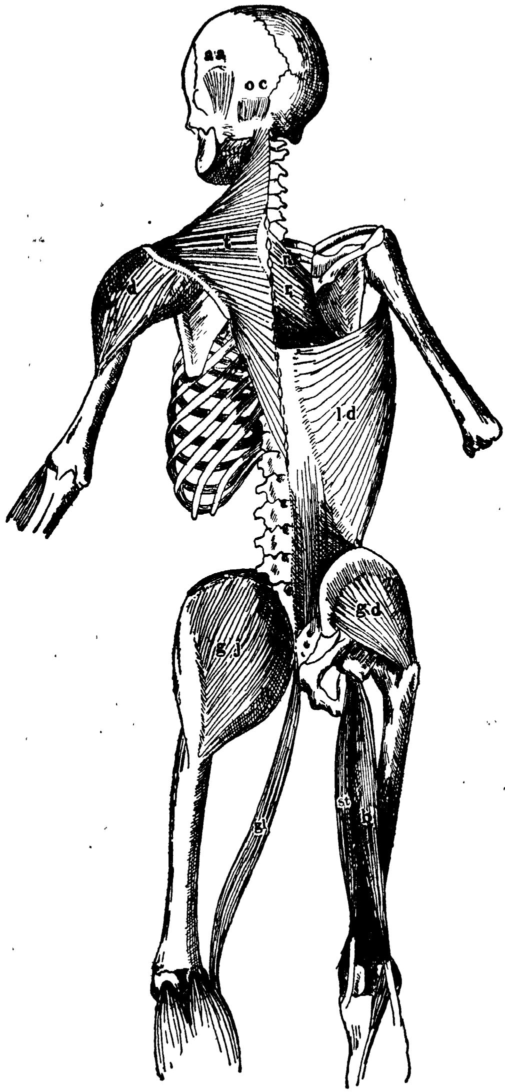
FIG. 143. Internal structure of a long bone (humerus); *a*, marrow cavity; *b*, hard bone of shaft; *c*, spongy bone; *d*, joint cartilage.

If a bone is treated with twenty per cent hydrochloric acid for several days, most of the mineral portion will be removed and the cartilage portion will remain. Though the bone does not look much changed, it has no stiffness and can be bent without breaking. The cartilage portion can be removed by thorough burning, and the mineral parts will not be greatly changed. Again the shape is not much altered but now the bone is brittle and has no elasticity.

Structure. If a long bone, such as that in the upper leg, be cut in two lengthwise, it is found to consist of several parts. There is a membrane covering the outside which helps supply nourishment and aids in repair of injuries. Then comes the outer layer of the bone itself which is dense and hard—then at the ends especially there may be a spongy region and in the center is a cavity filled with marrow and blood vessels.

The smaller bones are not hollow and the area of spongy bone varies considerably. In either case these are devices to promote lightness without sacrifice of strength. Microscopic study of bone shows that it is completely penetrated with blood vessels which provide nourishment for growth and repair. Bone is an active living tissue, not merely an inactive support like the heart-wood of a tree.

There are over two hundred bones in the human body. The principal ones are arranged as shown in the tabulation—



From Wilder.

Fig. 144. Diagram of human muscles, showing their relation to the skeleton. (After Eustachius.)

of the large hip bones and is much stronger and less movable than the shoulder girdle.

Functions. Bones have three chief functions:

1. They support and give form to the body.
2. They act as levers for the muscles.
3. They protect more delicate organs.

Many bones are examples of the first use, especially the spinal column and hip girdle. The long bones of the legs and arms are typical levers, and the skull and ribs are good examples of the protective function.

Muscles. We all know that muscles produce motion in our bodies. When the arm is bent rigidly the upper arm region enlarges and we speak of the size and hardness of our "muscle." This swelling is largely due to the contraction of the biceps, one of the many of our muscles, which number about four hundred and compose nearly half our weight.

We move our arm when we want to move it; that is, the muscles are under the control of our will and such muscles are called *voluntary* muscles. There are many other muscles which which operate our digestive, respiratory, and circulatory organs, which are not controlled by our will and are therefore called *involuntary*. This is not an accurate classification however, because some muscles are both voluntary and involuntary, as for instance those that operate the eyelid.

A better classification is based on the microscopic structure of the muscle fibres and makes three classes:

1. Those with striped fibres—most of the large muscles.
2. " " plain fibres—in most internal organs.
3. " " partly striped fibres—heart muscles.

The large body muscles are usually arranged in pairs which pull against each other, as in the arm. Here the biceps tends to bend the arm and the triceps at the back of the humerus tends to straighten it. Those muscles which bend a joint are called *flexors;* those which straighten a joint are called *extensors.* Normally the two sets pull against each other and hold the bones in place; the muscles support the skeleton just as truly as the skeleton supports the muscles.

Round shoulders and slouchy posture, either sitting or standing, are due to careless or lazy habits of muscle control. So much work is done while seated and with the body leaning forward, that it is easy to let the muscles relax, the shoulders sag and the spinal column bend over in a way never intended by nature. This restricts lung action and displaces the other internal organs, resulting in impaired health as well as poor appearance.

The state of mind influences our posture more than we realize. If we allow ourselves to feel afraid, our cringing, fearful attitudes will show it. If we think mean thoughts or are conscious of mean acts, we cannot so easily hold up our heads, look people in the eye and appear at our best.

In the same way posture affects our states of mind. Even if you are tired or discouraged, square your shoulders, pull in your chin, and you will feel better able to meet your difficulties. "Whistling to keep up your courage," "Keeping a stiff upper lip," and "Holding up your head" are not merely figures of speech but good hygienic advice.

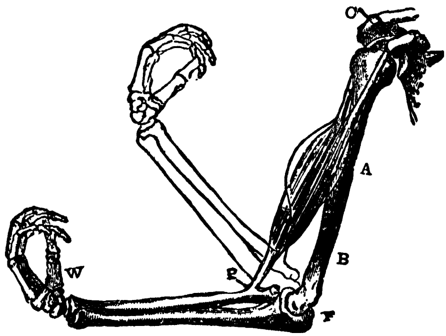
John L. Sullivan was once asked by an admirer, how he made such a wonderful success of his fighting. He replied, "Stick out your chest, you can do it as well as I can." While somewhat exaggerated this is in a measure true: the body affects the mind and the mind affects the body.

Action of Muscles. Muscles have the power to contract, that is, they shorten and thicken when doing work. In the large muscles, which are attached to the bones, one end is usually more movable than the other, hence when the muscle contracts the bone is moved.

To take the arm again as an example, the movable end of the biceps is attached to the radius bone of the lower arm, and its point of attachment can easily be felt with the fingers. The other end is attached to the shoulder by two tendons and when the biceps contracts the shoulder moves but little, while the forearm, acting as a lever, is bent through a large range of movement. In a similar way the triceps muscle straightens out the arm again.

Alternate contraction and relaxing of muscles produce motion in the body—sometimes with the help of bones, or sometimes without, as in the case of heart or intestinal muscles.

The only way to have strong and well controlled muscles is to use them. What we use we increase, and what we neglect, we lose. This is true of muscles and many other things. If we want strong bodies, we must exercise our muscles and they will become strong. If we would attain the perfect coördination of muscle and mental action of the skilled violinist, there is but one way, practice.



From Martin.

FIG. 145. Diagram showing the action of the biceps muscle in moving the arm.

One of the reasons for compulsory physical exercises in school is to correct errors of posture and develop an erect carriage of the body and healthful functioning of all its organs. No system of exercises, however excellent, will be of much use unless continuously followed, and carried into daily life. Correct posture is principally a matter of muscular training and should be continued until it becomes automatic.

Young people who are growing rapidly often have a temptation to relax and stoop at the shoulders or "slouch" forward at the hips. Both are bad habits, alike from the standpoint of health and appearance. If you are tall, be proud of it and stand up as nature intended ycu to. If you are short, make the most of your height, but don't try to add a "cubit to your stature" by high-heeled shoes. Be thankful that correct posture is easier for you than for your six-foot friend.

Walking is a daily exercise in posture development if we really have "learned to walk." With head and shoulders erect, but not stiff, a free stride with feet carried straight ahead walking becomes wonderful posture training. Yet notice how

few people really walk well or have endurance to walk far. How often this commonest method of locomotion is marred by rounded shoulders, cramped lungs, feet out of line or a slouching, loafing gait.

Even mere standing is seldom correctly done. The trunk should be erect, of course, and shoulders back enough to give the lungs room to expand. Heels should be together, back flat, and abdomen drawn in. The ideal is not exaggerated "military" bearing but such a posture as will permit easy balance, free breathing, and good appearance.

A person of normal health and figure can attain habits of good posture by the usual exercises of school and play and by constant application of these to his "daily walk of life." Correction of really abnormal conditions such as spinal curvatures and flat feet requires special exercises and treatment under guidance of an expert.

Like so many things in nature, the relation of posture to health is a sort of circle. Good posture tends to promote health by allowing lungs and other organs to function normally. On the other hand, good health tends to show in correct posture because we feel like standing straight and walking well. It is easy to start this circle and once begun, like any other habit, it "does itself." As mentioned elsewhere, mental attitude has great influence on bodily attitude. It is hard for a dishonest, mean, or cowardly person to stand straight or live straight.

Effect of Alcohol on Muscles. Muscle tissue composes over one-third of the weight of the body and most of the energy produced by our food is used in operating the muscles. Our physical strength is based upon muscle development; our motion and work upon muscle control. Anything which harms our muscle system is a serious matter and should be thoroughly understood.

Alcohol is sometimes used when especial effort has to be exerted, under the impression that it adds to one's muscular power. This is a serious mistake. True there is at first an apparent stimulant effect but this quickly disappears and a reaction follows, so that the total of energy and work is decreased.

This has been proved again and again by experiments with men and animals. Experiments made in the British Army by Dr. Parkes showed that even a ration of beer reduced the soldiers' ability to work from eighteen to twenty per cent. This experiment was repeated with various groups of men and with the same groups under different conditions and in each case alcohol, even in small amounts decreased ability to do muscular work.

Muscular control is exercised by the nerves and is seriously affected by alcohol. Not only does alcohol lessen our strength but it impairs our control of that strength, which is even more serious.

Again army experiments show that even small amounts of alcohol seriously affect precise control needed in target shooting. It has been repeatedly demonstrated in several armies that marksmanship was greatly harmed by use of alcohol and no officer would allow a rifle team to indulge in any such beverage when entering competition.

For a long time trainers for athletic teams have opposed or forbidden the use of alcohol for their athletes. They realize that this drug does not give even temporary help in muscular effort and that men who never use it at all are more nearly "in condition" at all times than those who use it even occasionally.

Every boy and girl wants to have a strong body; we all admire strength and skill and it seems strange that any one should deliberately adopt a habit which is proven to damage our strength, endurance, and control.

In this connection the lives of famous athletes are a good object lesson. Often we read with admiration of some young ball player or boxer who seems to carry all before him and to be on the way to success, both athletic and financial. Then how often the sudden rise and the new surroundings lead to careless habits of life and the career that started so brilliantly ends in premature eclipse.

On the other hand, there are examples of men like "Christy" Mathewson or Walter Johnson whose temperate manner of

life has made permanent their fame and extended their period of activity far beyond that of their less careful fellows.

To summarize:

Alcohol is a poor source of energy.
It reduces ability to work.
It reduces endurance.
It interferes with muscular control.
It tends to prevent success in physical effort.

COLLATERAL READING

Animals and Man, Kellogg, pp. 329–342; *General Physiology and Anatomy,* Eddy, pp. 221–293; *Biology of Man and Other Organisms,* Linville, pp. 439–448; *The Human Mechanism,* Hough and Sedgwick, see index.

SUMMARY OF CHAPTER XXXVIII

GENERAL STRUCTURE OF THE HUMAN BODY

1. **Body regions.**

2. **Body cavities.**

3. **Skeleton.**
    a. Composition of bone.
    b. Structure of bone.
    c. Names and number of bones.
    d. Functions of bones.
4. **Muscles.**
    a. Kinds.
        (1) Voluntary and involuntary.
        (2) Flexor and extensor.
        (3) Striped, unstriped, and combined kinds of fibres.
    b. Action of muscles.
        (1) Posture and health.
        (2) Exercise.
    c. Effect of alcohol on muscles.

CHAPTER XXXIX

FOOD

Vocabulary

Assimilated, made like and built into tissue.
Calorie, the amount of heat used to raise a pound of water 4 deg. F.
Vitamins, active substances in some foods, necessary to health.

Living things require energy. This energy depends in part upon oxidation and oxidation involves the union of oxygen with the tissues. The process destroys the substances oxidized, and necessitates the replacement of the oxidized tissue. Replacement of tissue means the taking in of *food,* which is a vital necessity to all living organisms.

If food is assimilated faster than it is used, growth, or storage of excess, results. In plants little energy is required and growth may be continuous; in animals a point is reached where oxidation balances assimilation and growth practically ceases.

Definition. Food may be defined as any substance which, when taken into a living organism, produces energy, builds tissue, or regulates the life processes, without harming the organism. The energy is necessary for any life, the tissue building may be to repair used organs or for growth.

The chemical composition of all living things is much the same. They are composed of a small number of elements and all living things depend upon the vitality of protoplasm for life. (See Chs. III, IV, V.)

Naturally the foods that produce these living tissues are also similar in composition, though numerous in kind. The general classes of food stuffs (nutrients) have been discussed in Chapter IV, where their composition and properties are tabulated, and grouped as inorganic and organic. Here we shall take up their functions in relation to the life and growth of animals, especially as food for man.

Functions of Inorganic Foods. *Water* constitutes about sixty per cent of all animal tissue, usually more than that in plants. It is a necessity to plants in starch making and in both plants and animals as a transporter and solvent for other foods. Though not oxidized in the body it is a very essential part of all foods. The blood and other body fluids are largely composed of water, and excretion of water in perspiration helps to regulate the bodily temperature.

Water should be freely used. Six glasses a day is not too much; it can be taken both at meals and whenever desired; too little water in the diet, especially in summer, may cause constipation.

Mineral salts compose about five per cent of all animal tissue. They are essential in formation of bone, teeth, blood, digestive fluids, and are used to supply nitrogen, sulphur, phosphorus, and iron for making protoplasm. Table salt, sulphate and phosphate of lime, and various iron compounds are important examples. Not only do mineral salts furnish elements for some of our body tissues, but they aid digestion, and are essential to the proper functioning of the blood and nerves. Phosphates which are found in whole cereals, meats, fish, and milk, aid in formation of protoplasm and bone and nerve tissue. Iron compounds which are obtained from green vegetables, prunes, meats, etc., are necessary in formation of red blood corpuscles and aid in carrying oxygen. Calcium compounds are important in bone formation and, together with magnesium compounds, help to regulate nerve and heart action. In fact, mineral compounds are sometimes called "regulating foods" because of their importance in this matter.

Functions of Organic Foods. *Proteins* are the only food stuffs containing nitrogen, and are therefore absolutely essential in production of living tissue. They include some of man's most valuable foods, such as lean meat, white of eggs, cheese, gluten in wheat, legumin in peas and beans, etc. Protein constitutes about eighteen per cent of the weight of man's body. The chief function of protein foods is to build tissue. They build anew and repair muscle and tendon, bone, cartilage, and skin

and also compose the corpuscles of the blood. Proteins may also be oxidized directly and thus furnish energy. While this actually takes place to some extent, it would be an expensive source of fuel and it would also put too great a strain upon the digestive and excretory organs if all energy were sought from this class of foods.

Proteins are found in greatest abundance in lean meat of all sorts (including fish, shell food, and fowl), milk, cheese, eggs, peas and beans, lentils, and nuts. There is also a fair amount of protein in cereals and bread (about 10 per cent), which are both building and fuel foods. Most foods contain some protein. Those above-mentioned are richest in protein and hence are termed "Building" or "Repair Foods."

The following is a list of the building and repair foods in the order of their cost, those giving most building and repair material *for the money* heading the list:

Beans (dried white)	Bread, whole wheat	Macaroni	Eggs (second grade)
Dried peas	Bread, graham	Mutton, leg	
Oatmeal	Salt cod	Beef, lean rump	Halibut
Cornmeal	Milk, skimmed	Milk	Porterhouse steak
Beans, dried lima	Cheese (American)	Beef, lean round	Eggs (first grade)
Bread	Peanuts	Lamb, leg	Almonds, shelled

The fats and carbohydrates are the chief energy producers. The former occur in fat meats, butter, fish, and eggs among animal foods, and in olive and cotton seed oils, nuts, corn, and cocoa from the vegetable world. The amount of fat needed varies with age, occupation, and other conditions but if more is taken than is required, it may be stored, almost unchanged, to be drawn upon if the energy supply becomes short. About fifteen per cent of the human body is fat tissue and much of our energy is derived from other amounts that are oxidized directly.

Carbohydrates (starches, sugars, and cellulose) comprise the bulk of man's nourishment. They are found in all vegetable foods, grains, potatoes, fruits, and nuts. Milk furnishes an important animal sugar. Though occupying so large a place in our menu, carbohydrates compose hardly one per cent of the

body's weight. This is because they are easily oxidized, furnishing much heat and bodily energy. If any excess is taken, it is changed into fat and stored as such.

Thus it is seen that while proteins, fats, and carbohydrates may all supply energy, neither of the latter can perform the proteins' function in growth and repair of tissues because proteins alone supply animals with nitrogen. However, the fats and carbohydrates serve to protect the valuable proteins by being first oxidized and saving the proteins for tissue building which they alone can perform. (See "Summary of Nutrients" at end of chapter.) Fats and carbohydrates are sometimes called "fuel foods" because their oxidation produces heat and supplies bodily energy.

The following list shows the main fuel foods, the great foundation foods of the diet, that supply energy for muscular work. Mental work requires so little extra fuel that it is not necessary to consider it specially. There are three groups of fuel foods. Here they are *in the order of their cost*, those giving most energy for the money heading the list.

1. *Starchy Foods*

Cornmeal	Rice	Split peas, yellow
Hominy	Macaroni	Dried navy beans
Broken rice	Spaghetti	Bread
Oatmeal	Cornstarch	Potatoes
Flour	Dried lima beans	Bananas

2. *Sugars*

Sugar	Candy
Corn syrup	Molasses
Dates	Most fruits

3. *Fats*

Drippings	Peanut butter
Lard	Milk
Salt pork	Bacon
Oleomargarine	Butter
Nutmargarine	Cream

About 85 per cent of the fuel for the body should come from these groups, using starchy foods in the largest amounts, fats next, and sugars least.

Vitamins. This important class of foods was discovered in 1917 by a Polish scientist, Casimir Funk. Their exact composition is not understood but their sources and functions are being

investigated and much is being learned about these valuable substances.

It was found that a diet restricted to a few foods, especially if they were cooked, did not always result in proper nourishment, even if the "balance" of protein, fat, and carbohydrate seemed correct. This led to the belief that there were additional substances in certain foods which were necessary to health and were destroyed or reduced by cooking.

Funk called these substances "Vitamins." Their functions seem to be varied and important. They stimulate cell activity, aid digestion, supply certain needed food substances, and affect the action of the blood. So far, three kinds of vitamins have been distinguished, designated by the letters A, B, and C.

Vitamin A is found in milk, butter, cream, eggs, liver, carrots, peas, spinach, and most green and yellow vegetables. While fats are about alike as sources of energy, they differ greatly as to Vitamin A. Vegetable oils and butter substitutes do not contain Vitamin A, unless they have been mixed with milk products in their preparation.

Vitamin B is especially abundant in tomatoes, beans, cabbage, spinach, lettuce, cereals, potatoes, and milk products.

Vitamin C is apparently not so widely distributed but is found in tomatoes, lettuce, lemons, oranges, raw carrots, onions, and apples.

The vitamins in tomatoes and cabbage seem to be little harmed by cooking. Most of the others are reduced or destroyed by heat.

All three vitamins are present to some extent in most of our common foods. A diet of the usual variety, including plenty of vegetables and uncooked foods will yield a suitable vitamin content. There is seldom need of taking special "medicated" foods to supply these substances.

Diet deficient in Vitamin A, may result in a disease of the bones called rickets, or an eye disease (xerophthalmia), as well as lack of normal development. Shortage of Vitamin B results in loss of appetite and may cause a disease of the nerves known as beri-beri. Deficiency in Vitamin C causes scurvy. Lack

Summary of Nutrients

Nutrients	Composition	Function	Foods containing
Proteins	C, H, O, N, S, P, K, Ca, Cl, Fe	Build tissue Protoplasm Some energy	Lean meats, eggs, beans, peas, milk
Carbohydrates	(C, H_2, O)	Energy Stored as fat Some tissue	Sugar, cereals, bread, cornmeal
Fats and oils	(C, H) O	Energy Stored as fat	Butter, lard, milk, cheese, olive oil, nuts
Vitamins	(?)	Regulate body functions	Green vegetables Fruits Milk products
Water	H_2O	60% tissue Blood, fluids Transporter	Taken as water in all vegetables, fruits, all foods
Mineral Salts			
Phosphates	H_3PO_4	Bone Protoplasm Aid digestion	Grains (whole) meats, fish, milk
Salt	NaCl	Essential in blood Appetizer	Taken as salt in almost all food
Iron compounds	$FeCO_3$	Hæmoglobin (Oxygen carrier)	Spinach, lettuce, green foods, prunes, meats
Potassium compounds	K_2SO_4	Essential in blood	Vegetables
Calcium and magnesium compounds	Ca, Mg	Regulate nerve and heart action	Grains (whole) Vegetables

of any vitamin in diet of children results in impaired health and growth.

A fourth substance which may prove to be another vitamin, is being investigated; it seems to affect the use of calcium compounds in the teeth.

Lipoid. A shortage of fat in the diet, not only reduces the energy produced, but has long been associated with a lowering of nervous activity. This is now explained by the discovery of a substance called lipoid, in all the cells of the body, especially in the outer layer of the nerve fibres and brain cells.

Lipoid resembles fat in many ways, but contains nitrogen and phosphorus which ordinary fats do not. It is affected by alcohol, anæsthetics, and poisons, and thus may be the means by which these act upon the system. At all events it seems to be derived from fat foods and is very essential to the nervous system.

Alcohol in Relation to Foods. Any substance that dissolves or is dissolved by lipoid, acts as an anæsthetic or narcotic. A narcotic is a substance which tends to cause diminished nerve action or even stupor. Alcohol dissolves lipoid and thus is considered as a narcotic. It is not a true stimulant as some suppose, and though oxidized in the body, is far from being a food, though this is sometimes claimed. A food must produce energy or tissue "without harming the organism" according to definition. Alcohol harms the organism in various ways and has no claim to rank as a food.

Alcohol is chiefly oxidized in the liver and the heat produced, is lost by the rush of the blood to the skin: uric acid is produced, which overworks both liver and kidneys. Dr. Irving Fisher of Yale says, "These heat values cannot be expended without at the same time poisoning the system with alcohol, so it is not even technically correct to count the heat value of alcohol as such." Alcohol produces some heat, but increases the loss of heat still more, so the net result is a lowering of body temperature, the feeling of warmth is an illusion due to the narcotic action on the nerves.

Beer does contain small amounts of unchanged sugars, but we already eat too much of these foods, and, supplied by beer, they would be fabulously expensive; beer does not promote

digestion either, and no one really uses it or any alcoholic beverage as a food, but rather for its narcotic effect on the nerves.

Alcohol cannot be classed as a food, because

1. Though oxidized, it produces a net loss of energy.
2. It does not build tissue.
3. It actually damages the protoplasm of the cells.
4. It has a narcotic effect on the nerves.

Measurement of Food Values. There is no way of measuring the tissue-building value of foods. But, since all produce heat when oxidized, this may easily be measured and their value as food computed in terms of heat produced. The unit of measurement is the "Calorie" which is the amount of heat required to raise the temperature of one pound of water four degrees Fahrenheit. Very careful experiments have shown that a man in an average day's work requires food enough to produce 2800 Calories of energy.

The amount of energy (number of Calories) required varies with age and occupation as shown in this table.

TABLE I

DAILY CALORIE NEEDS (APPROXIMATELY)

1.	For child under 2 years	900	Calories
2.	For child from 2–5 years	1200	"
3.	For child from 6–9 years	1500	"
4.	For child from 10–12 years	1800	"
5.	For child from 12–14 (woman, light work, also)	2100	"
6.	For boy (12–14), girl (15–16), man sedentary	2400	"
7.	For boy (15–16), (man light muscular work)	2700	"
8.	For man, moderately active muscular work	3000	"
9.	For farmer (busy season)	3200 to 4000	"
10.	For ditchers, excavators, etc.	4000 to 5000	"
11.	For lumbermen, etc.	5000 and more	"

The energy required for various degrees of exercise are shown below and one can compute the number of Calories used per day by multiplying the Calories per hour by the hours of each kind of exercise per day. Do this and see how near it comes to the estimate for a person of your age in Table I.

TABLE II

AVERAGE NORMAL OUTPUT OF HEAT FROM THE BODY

Conditions of Muscular Activity	Average Calories per Hour
Man at rest, sleeping	65 Calories
Man at rest, awake, sitting up	100 "
Man at light muscular exercise	170 "
Man at moderately active muscular exercise	290 "
Man at severe muscular exercise	450 "
Man at very severe muscular exercise	600 "

Food Proportions. In order that the body may have tissue-building foods and fuel foods in healthful proportions, we ought to eat from two to three ounces of protein per day, and enough fats and carbohydrates to make up the number of Calories which we may require as indicated above.

Since the fuel value of carbohydrates is only $^1/_2$ to $^1/_3$ that of fats, our diet should have two or three times as much carbohydrate, especially in warm weather, when the concentrated fuel of the fats is less needed. Still another way of reaching the same result is to take $^1/_{80}$ ounce of protein for each pound of our weight, and enough of the fuel foods (fats and carbohydrates) to make up the required number of Calories, for energy production. This makes a diet rather low in protein especially for growing children, but our usual mistake is to use too much, rather than too little protein, and one good authority sets the amounts even lower.

A safe proportion for growing boys and girls would be about 2 or 2½ ounces of protein per day, and enough fuel foods to supply the required energy, which will depend upon the age and activity as already stated.

The carbohydrates ought always to be more abundant than the fats, because of the much greater amount of energy produced by the latter. This is especially true in warm weather, when the proportion of four times as much carbohydrates will be about the proper diet.

If the above proportions are followed for all three food stuffs, the ratio for all will be approximately as follows:

protein, 1: fat, 1: carbohydrate, 4.

Not only should these proportions be maintained, but the foods should be so selected as to include plenty of green vegetables, fruits, and uncooked foods to supply the essential vitamins and mineral salts. Without the latter no diet can be considered well balanced and healthful.

The proportions of protein, fat, and carbohydrate in various foods, and the Calories produced by each, are shown in the Food Tables on pages 636–642 in the Appendix. These tables should be used in planning food proportions for correct diet.

Need of Mixed Diet. We require proteins, fats, and carbohydrates in about the proportions 1: 1: 4, but there is no one food that contains these nutrients in these proportions, so it is evident that a mixed diet is necessary. When foods are properly selected, so that the above proportion is obtained, we have what is known as a "balanced ration" and this should be the aim, both of those who prepare and those who eat foods.

If we use a diet largely of lean meat, we have too high a percent of protein. This excess is thrown off by the kidneys and intestines as waste. It overtaxes these organs seriously and is an expensive and unnecessary form of diet. In the same way an excess of fat much above the given proportion, such as would come from a diet rich in fat meats and butter, merely wastes the extra energy or stores it as unnecessary fat tissue in the body.

A strict vegetarian diet is almost sure to be too rich in carbohydrates and, as with a diet too rich in fats, fuel is wasted, too little tissue material is provided, and fat tissue may also accumulate from the starches being transformed and stored in this form.

Remember that, in general, most of the energy should come from carbohydrates and fats, and only enough protein be taken to provide for tissue building and repair. If our diet proves to be high in protein, we are burning tissue foods for fuel, as well as putting extra strain on our system, to remove the nitrogenous waste left by protein oxidation.

In general, man has learned to combine foods to correspond,

roughly, to these needs as will appear if we look up the composition of familiar combinations, like the following:

"Meat and potatoes," "Bread and butter," "Bread and milk," "Bread and cheese," "Pork and beans," "Potato and gravy," "Cereal and cream," "Ham sandwich."

A study of the food tables (pp. 636–642 in Appendix) will show the number of ounces of protein, and the fuel or energy values, of some of our common foods. The amounts of each food stuff taken are about the usual portion or "helping" which one would receive at table, so we can calculate how much protein and energy our present diet provides, and see if it corresponds to the amounts mentioned as suitable for our age and occupation.

From this table, also, it is possible to determine whether one's diet has the proper amount of fat and carbohydrate, in proportion to the protein, if one is using the 1: 1: 4 ratio as a basis.

Digestibility of Foods. Not only must the nutrients in our foods be present in the proper proportions, but they must be in a digestible form, or else they are wasted. Careful study shows that vegetable proteins and fats are not so easily digested as those from animal foods, though they seem to be cheaper.

This means that we must either use considerable animal food, or else increase the apparent amount of vegetable proteins and fats beyond the proportion suggested, because the body does not so readily digest them. This fact balances their cheaper cost to a great extent, and is also evidence that man is intended for a mixed diet, obtaining much fat and protein from animal sources, and his carbohydrate foods from the plants.

Cost of Foods. Not only must our diet be selected with reference to proper amounts of the nutrients and ease of digestibility, but also with regard to the cost in money. This is affected by three things: the actual price of the food, the amount of water and waste, and the expense of preparation. It is more and more important that we shall be informed as to the composition and cost of foods, and for this purpose the Government has published many bulletins, which can be had

free of cost, by application to the Department of Agriculture at Washington. Lists of all publications will be sent on application.

While we cannot devote enough space to the topic to compare the different kinds of food, their cost and composition, and methods of preparation, even a slight study of your own diet, in the light of this chapter, will show two facts: first, Americans eat more food than is required and second, they have an idea that the most expensive foods are the most nutritious.

These are serious mistakes, overtaxing both the digestive system and the pocketbook. No subject of our study is more important than the one giving us a clear idea of food values and selection.

Right and Wrong Diets. We are all too apt to let our artificial "tastes" and the demands of fashionable customs overrule our natural instincts and better judgment in the selection of foods. Costly, highly-seasoned, stimulating, and unnatural substances are frequent invaders of our digestive apparatus, to the detriment both of our bodies and our bank accounts. For the majority of people in normal health, meats, fish, eggs, milk, butter, cheese, sugar, flour, meal, potatoes, and other vegetables make a fitting and sufficiently varied diet—the main point being to use them in proportions suited to the actual needs of the body and not according to acquired whims of the "appetite."

From the American Museum of Natural History.

Fig. 146. A United States soldier in the field is allowed a daily ration supplying 4199 calories of energy. A typical daily field ration supplying this amount of energy is shown above.

Another fact that is often misunderstood, even after a study of

nutrients, is the very essential nature of mineral salts, especially iron, calcium, and potash compounds, which we obtain from green vegetables otherwise not rich in food value. As shown by the "Summary of Nutrients" on p. 394, these mineral compounds are a necessary part of every properly balanced diet. Furthermore, the fact that many foods, especially of vegetable origin, contain considerable indigestible matter such as cellulose, or connective tissue, is also of value for supplying a certain *bulk* of matter required to keep the digestive apparatus properly filled and active.

Fruits and vegetables are important for another reason. They produce alkaline substances when digested and these neutralize harmful acids formed by the digestion of proteins. They are also an important source of vitamins and cannot be safely omitted from the dietary, even though their Calorie value is not always very high.

If energy were all that is required of food we could get our 2500 Calories from about twenty ounces of sugar or white of egg, or half that amount of clear butter. Both our instinct and experience teach us that this would not support a healthful life.

A diet could be made up of highly concentrated and predigested foods which, though giving all necessary nutrients, would be very harmful, because of relieving the digestive organs of the work for which they have become adapted, and without which they will not remain in health.

Cooking. Man is the only animal which has learned to build a fire, hence is the only animal to use cooked food. This is not an unmixed blessing, for our digestive apparatus and especially our teeth are inherited from our animal ancestors, and, when provided with cooked food, are relieved of work for which they were adapted. This leads to disuse and so to degeneration. One seldom hears of the lower animals suffering from decayed teeth or indigestion, both of which are almost universal in man, due partly to too abundant, too delicately prepared, and unnatural foods.

Cooking of food performs three functions: first, it changes the mechanical and chemical condition so as to make it more

easily digestible; second, it makes food more appetizing in appearance or flavor, which quickens the flow of digestive fluids and actually aids digestion; third, the high temperature kills any dangerous bacteria, organisms, or parasites that the food may contain. This is very important.

Cooking meat develops its pleasing taste and odor, softens connective tissue, and makes it "tender," though too high temperature may harden the proteins of the lean portions. Beef extracts and thin soups are very agreeable to the taste, but contain very little nourishment since the meat proteins and fats are not soluble in water. These broths are useful as appetizers or mild stimulants but are of slight value as food.

Milk, if heated to boiling, is made less valuable as food partly because the vitamins are destroyed. When pasteurized, the heat is regulated so as to kill most bacteria, but not to reach a point high enough to impair its food value so seriously. When the *vegetable foods* are cooked the changes are chiefly the softening of the cellulose and the breaking of the insoluble walls around the starch grains, thus exposing them to digestive fluids and partly dissolving the starch in the hot water or steam.

In *baking* all flour foods, the aim is to make the material "light" and porous so as to be more easily broken up and digested in the alimentary canal. This lightness may be secured by the mere expansion of steam in the dough, but it is usually caused by use of yeast or baking powder, which produce carbon dioxide within the batter. The gluten (protein), always present in flour, is sticky enough to retain the gas, which expands with the heat of cooking, filling the loaf with countless bubbles and making it porous. Finally the heat stiffens the gluten and starch and drives out much of the enclosed gas and we have the "light," porous, and digestible bread or pastry, instead of an indigestible paste of uncooked flour and water.

"Special Foods." There are no special foods for special organs. Fish is not a "brain food," nor celery a "nerve food," nor meat a "muscle food." The savage eats the heart of his fallen foe to absorb his courage, but we ought to be beyond that stage. If we use a properly balanced diet our cells will

select what they need in proportion as we use them. The only way to increase the brain power is to use the brain—not by eating foods rich in phosphorus because the brain tissue contains this element.

If eating strong muscle made us strong, we ought to have a diet of the toughest meat possible. However the only way to persuade nature to give us more strength, is by using what we have and furnishing her a proper food supply to select from.

To be sure, if phosphorous compounds are lacking, the nerves will suffer; if protein be absent, our muscle tissue might feel the lack; but in a balanced diet this is never the case. An excess of any element, above what is normally used in the body, does not develop any special part, but is merely wasted. Extra protein is not needed for extra work; it is the fuel food that supplies the energy, the protein requirement being almost constant for all grown persons and only slightly varying for younger people.

Food Preservation. Food for man and his domestic animals is also food for bacteria and other organisms. It is subject to oxidation and decay, like other organic matter, and must be protected if it is to serve man as food. Bacteria require moisture and warmth for growth and are killed by heat and certain chemical substances. Foods are preserved by utilizing these facts.

Moisture may be removed, *i. e.*, the food is "dried." This is used for hay, cereals, and some fruits. Bacteria do not thrive unless warm, hence "cold storage" and refrigerators are used to preserve meats, eggs, fish, and milk products.

Heat kills bacteria, therefore many foods are sterilized by heat, then sealed so that no more bacteria can gain entrance and will keep fresh almost indefinitely. The enormous canning industry is based on this process.

Salt and substances produced by smoke are preservatives which hinder bacterial growth but do not harm the food. Much meat and fish is preserved by smoking and salting or by salt alone. Other preservatives, such as benzoate of soda may be used, possibly without harm to the consumer, but they

might allow the canning of foods that had begun to decay and so were unwholesome. The number of permissible preservatives is small and if used, the maker is compelled by law to state the fact on his labels.

Food Adulteration. Food may be adulterated by the addition of harmful or less valuable materials or by the removal of any useful portion. Milk may be adulterated by the addition of water or preservatives, or by removal of part of the cream. Canned goods may be adulterated by the addition of excess water, preservatives, or harmful coloring matter.

A few years ago, cereals sometimes had bran, peanut shells, or even sawdust added. Candies, jellies, and preserves were sweetened with glucose instead of cane sugar. The list of possible adulterations is too long to take up in detail. Sometimes the food was actually harmful to use and sometimes the damage was only to the pocketbook, but conditions reached such a pass that something had to be done. Various state laws were passed, trying to regulate food conditions and in 1906 the Federal Food and Drug Law was enacted. This law has established standards for the composition and preparation of many foods such as meats, milk, butter, ice-cream, cereals, flour, flavorings, coffee, and many others. These standards must be met by the producer and they give the consumer a definite idea of what he has a right to expect.

The law also requires that foods be truly labeled as to composition, preservatives, or coloring matters if any, and as to weight or quantity. Thus if a customer will read his labels he can know what he is buying and act accordingly. Harmful preservatives, flavors, and colors are forbidden; certain others, not harmful, are permitted but their presence must be stated on the package. Conditions of manufacture, especially in the meat-packing industry, are under government control. Food substitutes such as oleomargarine and artificial food fats are under careful supervision.

The law also applies to patent medicines and requires the label to show the presence of alcohol, morphine, cocaine, or other harmful drug if any be present. Also no false or mis-

leading claim may be made as to the curative properties of any medicine.

The Food and Drug Law does not necessarily make all foods wholesome but it does enable the customer to demand certain standards and to know what he is buying if he will take the trouble to read the labels.

Foods and Disease. Foods that have been kept too long, that have been exposed to flies or dust, or contaminated by handling, may become carriers of disease germs. Notice whether your dealer keeps his supplies protected from flies and dust and whether his store and person are clean.

Milk is more easily contaminated than most other foods, and requires especially careful handling. Its use is so general, and so necessary for children that too much care cannot be exercised in securing pure milk. Germs of typhoid fever, diphtheria, scarlet fever, and tuberculosis have been known to be carried by milk and almost every community has some regulations governing its milk supply. So far as possible cows and stables are inspected and kept clean. Diseased cows are killed. Helpers are required to pass health examinations lest they infect the milk in handling it. The milk is shipped at low temperature in clean cars and is subject to constant inspection before going on sale.

Even with all these safeguards, the milk supply of a large city is such a widespread business that complete safety can only be secured by pasteurizing. This, as explained in Chapter XVII, kills the disease germs without greatly changing the food value of the milk.

Milk and other foods, even if pure when purchased, may be contaminated in the home if not kept cool, in clean dishes and out of reach of flies.

Water is sometimes a carrier of typhoid or other germs, but this has been realized for a long time and pretty well guarded against. City reservoirs are protected from pollution, the water shed is carefully guarded, and the water itself is filtered and chemically treated to remove dirt and bacteria. Where water is obtained from wells, great care must be taken lest

drainage from toilets or stables reach the water supply. I water from a suspected source must be used it is better to boi it and then keep it cool with ice until consumed.

COLLATERAL READING

Principles of Nutrition, Atwater, entire; *Studies in Physiology*, Peabody pp. 41–61; *Elements of Cookery*, Williams and Fisher, pp. 136–142, lool through; *Chemistry of Common Things*, Brownlee, pp. 242–265; *Foo Materials*, Richards, pp. 1–19; *Pure Foods*, Oleson, pp. 1–32; *Plants an their Uses*, Sargent, look through; *Source, Chemistry and Use of Fooa* Bailey, look through: *World's Commercial Products*, Freeman, see index *Food and Dietetics*, Hutchinson, see index; *Practical Hygiene*, Harring ton and Richardson, see index; *Feeding the Family*, Rose, entire; *Huma Foods*, Snyder, see index; *Children's Diet in Home and School*, Hogan, se index; *Food and Dietetics*, Norton, see index; *The Cost of Food*, Richard and Norton, entire; *Foods and their Adulteration*, Wiley, see index; *Phy siology, Experimental and Descriptive*, Colton, pp. 167–193; *Textbook i General Physiology and Anatomy*, Eddy, pp. 51–89; *Applied Physiology* Overton, pp. 51–66; *Human Mechanism*, Hough and Sedgwick, pp. 95–97 *The Human Body and Health*, Davidson, pp. 35–44; *The Human Body* Martin, pp. 88–105; *General Science*, Clark, pp. 60–69; *Elementary Physi ology*, Huxley, pp. 250–252, 291–303; *High School Physiology*, Hewes pp. 87–91; *Essentials of Biology*, Hunter, pp. 330–350; *U. S. Departmen of Agriculture*, Farm Bulletins, 23, 34, 74, 85, 93, 128, 142, 182, 249, 256 295, etc.; *Periodical*, "The Forecast," Philadelphia.

SUMMARY OF CHAPTER XXXIX

FOOD

1. **Necessity.**
   a. Living things use energy.
   b. Energy is released from food by oxidation.
   c. Oxidation destroys tissue.
   d. Tissue is replaced by food.
   e. Additional food used for growth and storage.

2. **Definition.**

3. **Classification of food stuffs.**
   a. Inorganic.
      (1) Water (60%).
         (a) Composition.
            1. H_2O.
         (b) Functions.
            1. Transportation.
            2. Solvent. 3. Photosynthesis in plants.
         (c) Source.
            1. Nearly all foods.

(2) Mineral salts (5%).
  (a) Composition.
    1. Phosphates, nitrates, chlorides, etc.
    2. Compounds of N, S, P, iron, lime, etc.
  (b) Function.
    1. Formation of bones, teeth, blood, fluids, etc.
  (c) Sources.
    1. Milk. 3. Cereals.
    2. Vegetables. 4. Eggs.

b. Organic.
(1) Proteins (18%).
  (a) Composition.
    1. C, H, O, N, S, P, etc.
  (b) Function.
    1. Essential to living tissue.
  (c) Sources.
    1. Lean meat. 4. Cereals.
    2. Eggs. 5. Peas.
    3. Cheese.
(2) Fats (15%).
  (a) Composition.
    1. C, H, O.
  (b) Function.
    1. Produce energy.
  (c) Sources.
    1. Fat meat. 4. Oils.
    2. Butter. 5. Etc.
    3. Lard.
(3) Carbohydrates (little in tissues).
  (a) Composition.
    1. C, H_2, O.
  (b) Function.
    1. Produce energy or stored as fat.
  (c) Sources.
    1. Sugar in cane, beet, fruit, milk.
    2. Starch in cereals, vegetables, etc.
    3. Cellulose in vegetables.
(4) Vitamins.
  (a) Function.
  (b) Sources.

4. Lipoid.

5. Alcohol in relation to foods.

6. Measurement of food values.
a. Meaning of "Calorie."
b. Average person needs about 2800 Calories daily.
c. Need varies with age, occupation, and climate.

7. Food proportions.

a. Proteins, two to three ounces per day.
b. Fuel food to give remainder of Calories.
(1) Fats, one part.
(2) Carbohydrates, two to four parts.
c. General ratio.
(1) 1 part protein, 1 part fat, 4 parts carbohydrates.

8. Need of mixed diet.

a. No *one* food has nutrients in correct ratio.
b. Animal food would be too high in fat and protein.
c. Vegetable food would be too high in carbohydrates.
d. Excess of protein, a dangerous and expensive source of energy.

9. Digestibility of foods.

a. Vegetable fats and proteins less digestible than animal.
b. Value of both vegetable and animal foods.

10. Cost of food.

a. Depends on price, waste, cost of preparation.
b. Reasons for expense.
(1) Poor selection.
(2) Bad preparation.
(3) Waste.
(4) Demands of artificial appetite.

11. Proper diet.

a. Value of simple, standard foods.
b. Objections to highly seasoned or "fancy" dishes.
c. Importance of green vegetables for mineral salts.
d. Concentrated foods not good, bulk needed.

12. Cooking.

a. Functions.
(1) Makes food more easily digested.
(2) Makes food more appetizing.
(3) Sterilizes food.
b. Faulty cooking may make food less digestible.
c. Boiling *vs.* pasteurizing milk.
d. Effect of cooked food on teeth.

13. No foods for special organs.

14. Food preservation.

15. Food adulteration.

16. Foods and disease.

CHAPTER XL

NUTRITION

Vocabulary

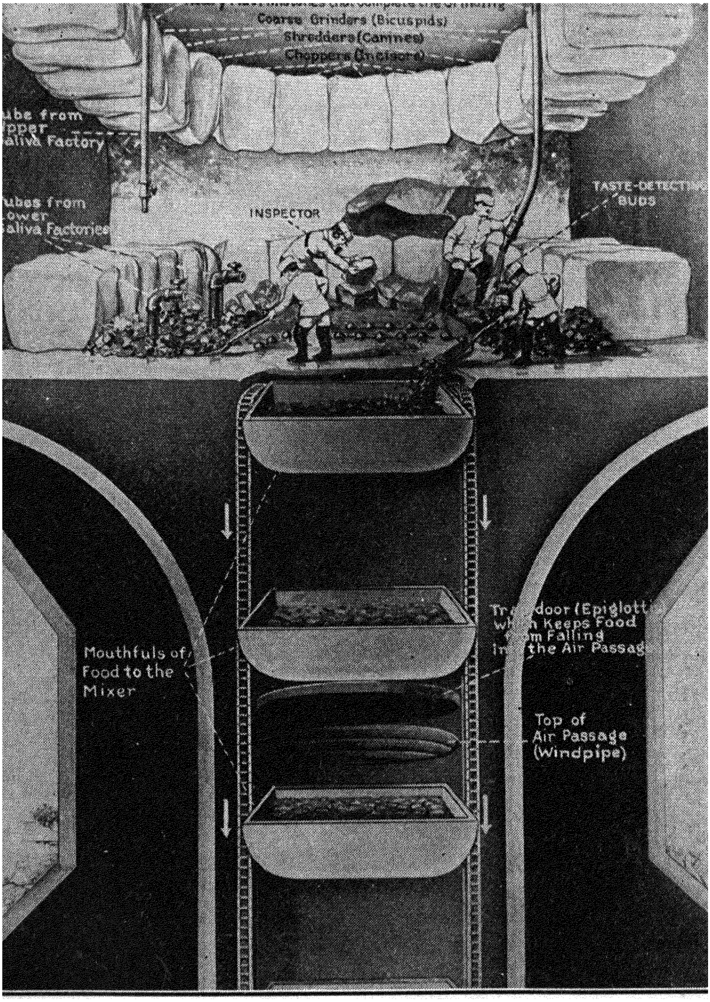
Nutrition, all processes concerned with building up tissue
Alimentary, pertaining to food or nutrition.
Enzyme, a substance inducing chemical changes in digestion.
Lacteals, lymph capillaries of the intestine which absorb fat.

Someone has said, "We live, not on what we eat, but on what we digest." Food, even after cooking, is not in condition to be made into tissue or to furnish energy.

Digestion produces two important changes in foods. First, it makes them soluble to allow transfer by osmosis; second, it changes them chemically to permit them to be assimilated. These changes are brought about in two ways, first, *mechanically* by the teeth, the motion of the stomach, and intestinal walls, second, *chemically* by active substances in the digestive fluids, called enzymes or ferments. The latter are the more important means of digestion; there are several kinds, each acting on a particular foodstuff and each secreted by different glands in various parts of the digestive tract. They will be referred to later when these different regions are studied.

Digestive Organs. The digestive tract or alimentary canal is practically a continuous tube with many glands opening into it to furnish digestive fluids, also with a rich blood supply to provide for its activities and to remove digested foods. This food tube consists of three general regions whose structure and functions will be studied in order, the mouth, the gullet and stomach, and the intestines.

In the simpler animals the digestive canal may be lacking (protozoa), or almost straight and uniform in size (worms), but in the higher animals and man it is much coiled to provide greater surface for secretion and absorption. It also varies



*From Compton's "Pictured **Encyclopedia**"—F. E. Compton & Co.*

FIG. 147. In the Grinding Mill. This diagrammatic picture shows the grinding mill where fuel (food) is received and worked into shape for the succeeding processes. Here we see inspecting, grinding, and mixing before the food is sent down through the trap door to the mixing room (stomach).

much in diameter, to permit the carrying out of special functions in various parts.

The Mouth. So far as digestion is concerned, the mouth performs two functions: in it the food is crushed or cut into smaller portions and at the same time it is mixed with saliva, one of the digestive fluids, whose function will be dealt with later. The mouth cavity is bounded above by the palate, below by the tongue, and at front and sides by the teeth, lips, and cheeks. There are six openings into this cavity, from within, namely:

1. Two nasal openings, behind the palate and connecting with the nostrils, above.
2. Two Eustachian tubes, also far back, high up at the sides and connecting with the ears.
3. The trachea and gullet below, the former in front and connecting with the lungs, and the latter behind it and communicating with the stomach.

Other organs are immediately connected with the mouth cavity, most of which can be seen by studying your own mouth with a mirror or by looking into a friend's mouth with a small electric light. The "roof of the mouth" or hard palate can be easily recognized. Back of it is a downward projecting sheet of muscle, the soft palate; at either side rounded projections may be seen, which are tonsils.

Behind the soft palate and near the opening into the nasal cavity is the location of *adenoid* growths which may obstruct the breathing and have to be removed if they reach abnormal size. The tonsils also sometimes become enlarged and act as nests for bacterial growth, necessitating their removal. Their function is not thoroughly understood, and when diseased their removal is beneficial.

The openings of the Eustachian tubes are protected by their high location and are usually closed. The trachea is protected by the base of the tongue and the epiglottis, which is a door-like organ that covers the trachea during swallowing.

The Tongue. The tongue is easily studied, but few of us really know its shape, size or structure. The best way to find out is to look at it. It is a large muscular organ, nearly filling the

front part of the mouth cavity when the jaws are closed. It has great freedom of motion and performs the following functions:

1. It is the organ of taste—a sense which aids in selecting foods and in promoting their digestion.

2. It aids in chewing, by automatically keeping the food between the teeth.

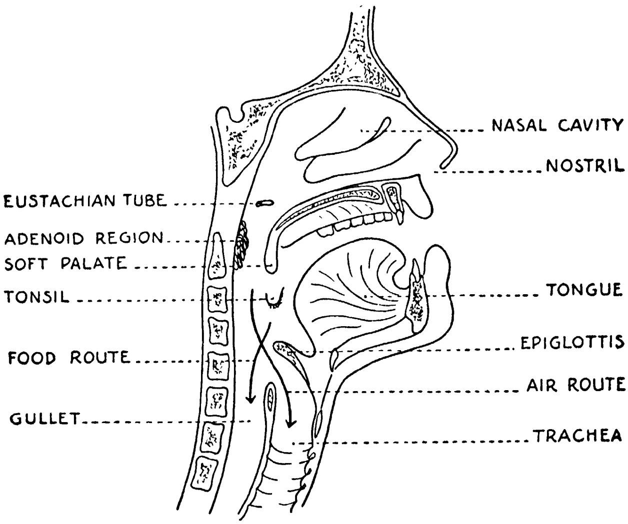


FIG. 148. Diagram showing the relative position of the organs of the nose and throat.

Note especially that the course taken by the food in swallowing crosses that of the air in breathing; this makes necessary the adaptations mentioned in the text, to prevent food from entering the trachea when it is being swallowed.

Attention is also called to the size and thickness of the tongue, which we usually think of as long and thin. Its base helps protect the opening of the trachea when swallowing.

Note the large size of the nasal cavity and the projecting lobes which help to warm and moisten the air, catch dust and provide surface for the nerves of smell.

3. It is concerned in the process of swallowing, since it rolls the food into proper shape, pushes it back toward the gullet, and partly closes the trachea.

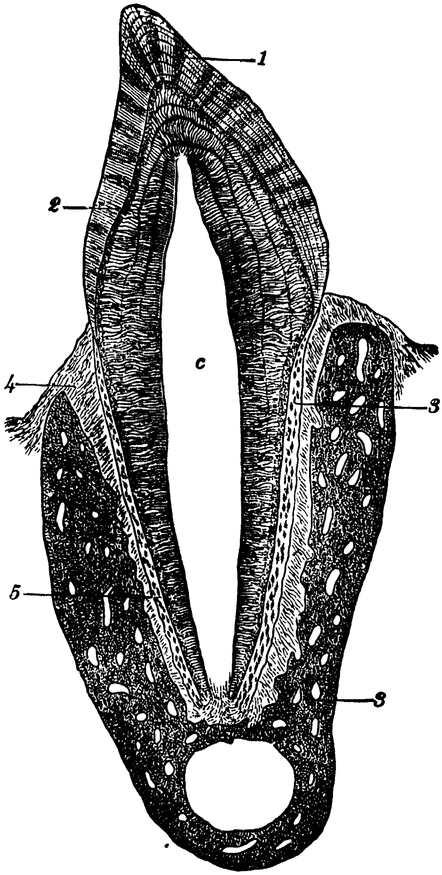
4. It helps to keep clean the inner surface of the teeth.

5. In man it is one of the organs concerned in speech.

The Teeth. The teeth are familiar and important organs. Each consists of three parts, (1) the crown or exposed portion,

(2) the neck, a slight narrowing at the edge of the gum, and (3) the root or roots which are attached to the jaw.

A section cut lengthwise through a tooth shows that the crown is covered by a very hard substance called enamel, which protects the exposed parts. The bulk of the tooth consists of dentine, a softer and more porous substance. The center is occupied by the pulp which contains the nerves and blood vessels of the tooth. The root is covered by a bone-like coating, the cement, and through the very tip is the opening by which the nerves and blood vessels find entrance.



From Martin.

FIG. 149. Section through a premolar tooth of the cat still imbedded in its socket. 1, enamel; 2, dentine; 3, cement; 4, the gum; 5, the bone of the lower jaw; c, the pulp-cavity. Human tooth is similar in structure.

Number and Kinds of Teeth. It is easily seen that there are four kinds of teeth in the mouth even though the full number may not be there till the 20th year.

In the full set there are thirty-two, sixteen on each jaw, arranged as follows: In front are eight incisors with sharp edges, whose function is to cut the food, next on each side is one canine, or four in all, which are pointed and which the lower animals use for tearing food. In

man they assist the incisors. Behind these on each side come two premolars and three molars, all with rough flat crowns and used to crush the food. The first or "milk" teeth lack the premolars and one set of molars hence number but twenty in all. The reason for having two sets is to allow for the growth of the jaw. Hence, if the first teeth are allowed to decay and are pulled too soon, the jaw never gets its proper shape and the later teeth are crowded and irregular. At the proper times the roots of the first teeth are absorbed and they make way easily for the permanent teeth and the jaw is developed into proper shape.

The numbers of teeth are often expressed in fractional form, and are easily remembered in this way. Beginning at the front in the middle of the jaw and putting the upper teeth above and the lower teeth below, we have the "dental formula" for the adult and first sets as follows:

	Incisors	Canines	Premolars	Molars
First set (20)	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{0}{0}$	$\frac{2}{2}$
Permanent set (32)	$\frac{2}{2}$	$\frac{1}{1}$	$\frac{2}{2}$	$\frac{3}{3}$

The last pair of molars may not appear till about the twentieth year and are therefore called the wisdom teeth, as one is supposed to have acquired some wisdom by that time.

Among other animals the teeth vary a great deal in size and number, but there is none that has a greater variety of kinds. Horses and cattle have molars greatly developed, cats and dogs have canines long and sharp, while rats and squirrels develop the incisors excessively for gnawing. Vegetable foods require broad grinding teeth, while animal food needs sharp canines and shear-cutting premolars. Man, being adapted for a mixed diet, has all forms moderately developed. Chewing is one of the mechanical processes which prepares the food for chemical action by the digestive fluids.

Glands. Digestive fluids are secreted by organs called glands.

A gland consists of a group of cells adapted for producing a fluid secretion. These cells are developed on the inner walls of a cavity which usually opens into some other organ by way of a tube called a duct.

These cavities may be simple and very small, like the mucous glands that moisten all the digestive tract, or they may be very large and complex like the liver. In either case they must have

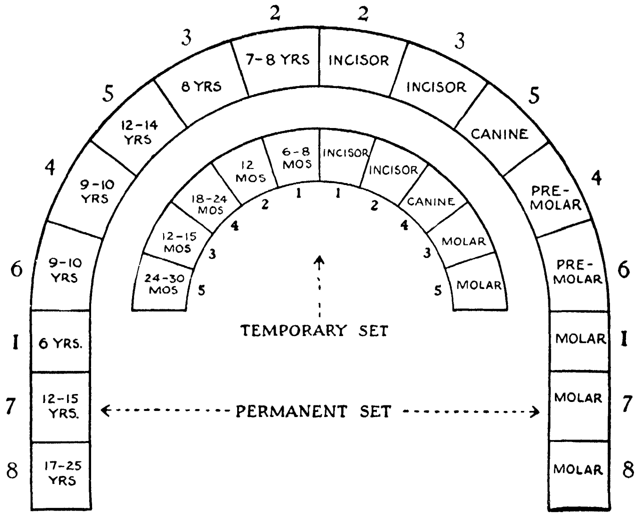


FIG. 150. Chart showing the order of succession and time of appearance of both sets of teeth. The numbers indicate the order in which the teeth of each set make their appearance. The age at which each kind of tooth usually develops is shown at the left and the names of the teeth are indicated at the right.

a rich blood supply and nerves to control it and the action of the gland, as well. A gland, then, consists of the secreting cells, the gland cavity, the ducts, the blood and nerve supply.

Salivary Glands. The principal glands of the mouth are the salivary glands of which there are three pairs. The largest pair is located beneath the ear on each side of the head and the ducts open opposite the second upper molar. Inflammation of these glands causes the mumps. The sub-maxillary glands lie within the angles of the lower jaw and the sub-lingual pair are below the tongue, beneath the floor of the mouth; ducts from both pairs open under the middle of the tongue.

Saliva. Saliva is a thin, alkaline fluid containing the enzyme ptyalin, which changes starch to soluble sugar, but this action is slight, since the food remains so short a time in the mouth. However, the other functions of saliva make it important that it be thoroughly mixed with the food, since its presence in the stomach stimulates the gastric glands. It also permits foods to be tasted, since, only in solution will the food affect the nerves of this sense. Furthermore, saliva aids in chewing and is indispensable in swallowing food, so that its digestive function is only one of several. The quantity secreted is much greater than one might suppose, being about three pints per day.

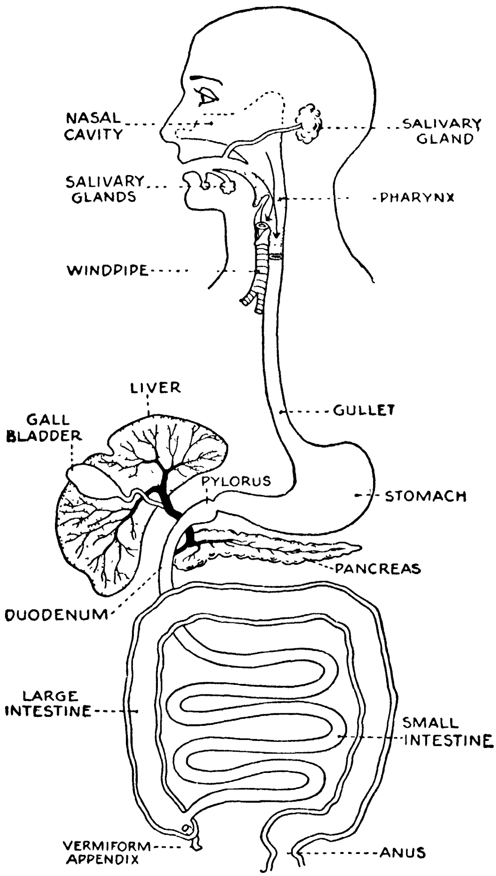


FIG. 151. Diagram showing principal parts of the human digestive system. The head is enlarged to show the details of mouth and throat;—all structures are much simplified.

The steps of the digestion process in the mouth, then, are

1. Food mechanically crushed.
2. Food moistened for taste and swallowing.
3. Some starch changed to sugar by saliva.

The Stomach. Passing from the mouth, the food enters the gullet, which at a distance of about nine inches enlarges into the stomach. This organ is located just beneath the diaphragm with the inlet at the left and close to the heart. Except when fully distended it is not the smooth, pear-shaped organ usually pictured, but may be collapsed and empty, or almost any irregular shape, depending on its contents, and muscular movements.

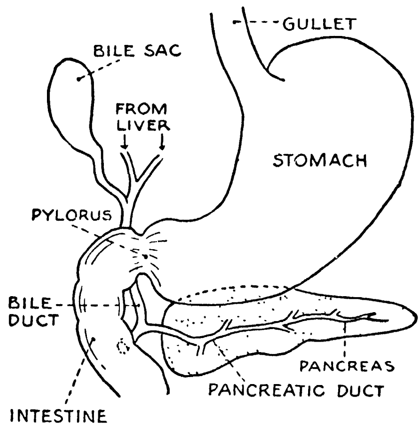


FIG. 152. Diagram showing shape of stomach when filled out, and indicating the relative positions of the liver and pancreas and their ducts. When empty the stomach is irregular in shape, and when occupied with food is constantly changing in outline as its muscles contract and squeeze the food.

Its function is very largely to store and finely divide the food. We usually eat at one time enough food to last for several hours. This food must be stored somewhere and the stomach provides the place. Also, chewing has only partly divided the food, so a second function of the stomach is to furnish the mechanical separation of the food particles by the churning motion of its muscular walls. The walls are also provided with millions of simple glands which secrete the gastric fluid at the rate of five to ten quarts per day.

Gastric Fluid. This gastric fluid contains hydrochloric acid and two enzymes, rennin and pepsin. The rennin acts on the casein (milk protein) changing it to curd, in which form it is more easily digested by other ferments.

(Note: rennin is used to "start" cheese and in "junket tablets," the latter made from calves' stomachs.)

Pepsin, acting only in the presence of an acid, changes some proteins to soluble peptones and also dissolves much connective tissue, thus exposing a greatly increased food surface for diges-

tion in the intestine. Do not get the idea, that all or even a great deal of protein food is completely digested in the stomach; in fact, as fast as they are finely divided, many proteins are discharged into the intestine where the pancreatic fluid completes the major part of protein digestion.

The stomach, then, performs four functions, namely:

1. It acts as a storage for food.
2. It mechanically divides and separates food particles.
3. Rennin curdles casein.
4. Pepsin acts on some protein and connective tissue.

Thus it is apparent that "stomach trouble" and digestive trouble *may* not mean the same thing, and despite the common idea, the bulk of digestive processes do not take place in the stomach but in the small intestine.

The food as it is discharged into the intestine is called chyme and consists of

1. The fats all unchanged.
2. Most of the carbohydrates.
3. A large portion of the proteins.
4. Some sugars, peptones, and water, which were not absorbed in the stomach.

It is evident that, so far, the food has been mainly prepared *for* digestion rather than digested, a process that is chiefly accomplished in the small intestine.

The Intestine. The stomach connects with the small intestine by way of a muscular valve (the pylorus) which prevents the food from passing before it is thoroughly broken up in the stomach.

The intestine is the most important portion of the digestive tract, and consists of a coiled tube about twenty-five feet in length. The part next the stomach is about twenty feet long, about one inch in diameter and is called the *small intestine*, while the remaining five feet are over two inches in diameter and are called the *large intestine.*

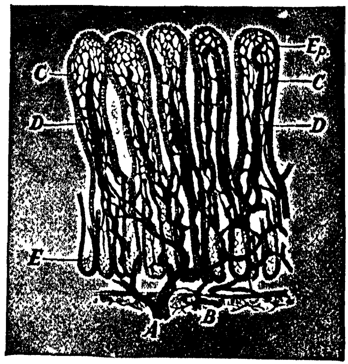
The small intestine joins the large at the lower, right side of the abdomen, and at this point is the location of the appendix. Inflammation of this organ is called appendicitis.

Adaptations for Increase of Surface. In order that both secretion of fluids and absorption of food may go on, much surface (for osmosis) is required.

For this increase of surface, the intestine is adapted in three ways:

1. Its great length and coiled position in the body.
2. Its inner lining projects in creases and folds.
3. The lining of the small intestine is thickly covered with microscopic projections called villi.

The villi are so fine and so numerous, that, under a lens, the intestinal lining looks like a piece of velvet. By these means the absorbing surface is increased five times, so that the total area of the intestine is not less than twenty-five square feet, or about twice as great as that of the skin.



From Cadiat

FIG. 153. Mucous membrane of the small intestine of the dog. *A*, artery; *B*, vein; *C*, capillaries; *D*, lacteals; *E*, glands; *Ep.*, epithelial tissue.

Muscular Action. The intestinal walls are provided with layers of involuntary muscles which perform two functions by their contraction and expansion.

1. They mix and separate the foods, thus constantly exposing it to digestive action.
2. They keep the food moving slowly through the digestive canal.

The efficiency of digestion and absorption depends as much upon these muscular movements as upon the chemical action of the digestive fluids, themselves. To provide the fluids for intestinal digestion there are three kinds of glands, (1) the intestinal glands, (2) the liver, (3) the pancreas.

Intestinal Glands. The intestinal glands are small, simple and very numerous, located in the lining among the villi. They secrete a strongly alkaline fluid containing sodium carbonate and also enzymes that act on starches and sugars. This sodium carbonate (and other alkalis from the pancreatic fluid) combine

with part of the fats, forming soaps, which help to prepare these fats for absorption.

The Liver. The liver is the largest gland in the body. It is located between the diaphragm and stomach, thus being the uppermost of the abdominal organs. The *secretion* of the liver is called *bile* and is a thick brown liquid, of which about one quart is produced daily. This is stored temporarily in a sac called the gall or bile sac. Bile has several important functions, as follows:

1. Bile is, itself, partly waste substance, removed from the blood.
2. It aids in digestion and absorption of fats.
3. It stimulates the action of the intestine.
4. It tends to prevent decay of intestinal contents.

The chief digestive action of the bile is on the fats which it makes into a milk-like emulsion to be absorbed by the lacteals. If it is prevented from entering the intestine, over half of the fats eaten are not absorbed.

Another important function of the liver is the storage of excess carbohydrate in the form of *glycogen* or liver starch which the body may draw upon as a source of energy in emergencies. The liver, then, excretes waste, secretes a digestive fluid, and stores food.

Pancreas. Lying between the lower side of the stomach and the first fold of the intestine is the pancreas, whose secretion is by far the most important in producing the chemical changes of digestion. The pancreatic fluid is strongly alkaline, and contains three enzymes: trypsin, amylopsin, and steapsin.

The trypsin resembles pepsin and completes the digestion of the proteins, changing them into soluble peptones. The amylopsin (like the ptyalin of saliva) changes starch to sugar, while the steapsin changes fats to fatty acids and glycerin, which are easily absorbed.

The pancreatic fluid also emulsifies fats and completes the digestion of food after it has undergone the preparatory steps of (1) chewing, (2) salivary digestion, (3) gastric separation, (4) gastric digestion.

Absorption. The general purpose of digestion is to put the foods in a soluble form so that they may pass through the body's membranes by osmosis.

Absorption is the name given to the passage of digested food materials from the digestive tract to the blood or lymph. However, absorption in a living animal is not merely a mechanical "soaking up" of prepared foods, but other changes take place, as the products of digestion enter the circulation.

Absorption may take place (1) directly into the blood capillaries which richly supply the walls of the stomach and intestine or (2) indirectly, by way of the lymph capillaries of the villi (lacteals) which eventually empty into the blood circulation also.

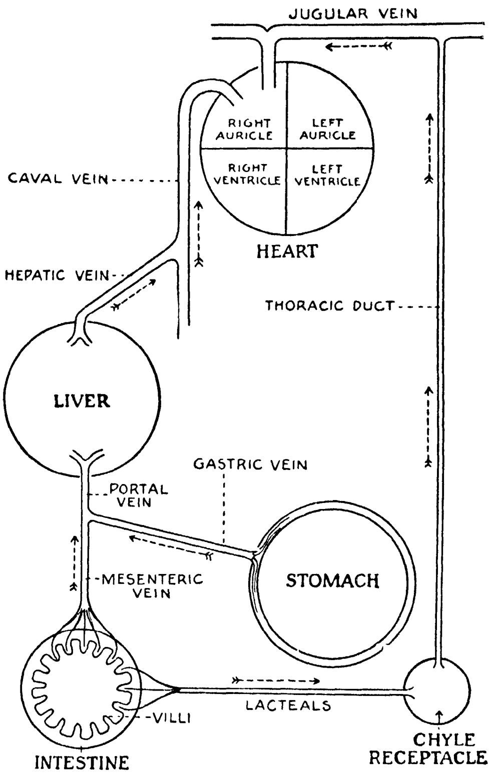


FIG. 154. Chart showing the course of digested foods in the process of absorption.

The capillaries of the gastric vein in the stomach walls absorb some water, a little digested protein, and still less sugar, but the principal region of absorption is in the villi of the small intestine. Here the thin walls and enormous surface bring the digested foods close to the blood and lymph capillaries. Peptones, sugars and fatty acids, salts and water are passed into the

blood stream, while the fats that have been emulsified are taken up by the lymph capillaries (lacteals) and carried by the lymphatic circulation to the thoracic duct and finally emptied into the general circulation, near the left jugular vein.

Assimilation. All the steps of digestion and absorption lead to the final process of assimilation, which either builds up the cells or supplies them with fuel. For this purpose the blood carries the absorbed foods to the tissues. These foods pass as lymph (by osmosis) from the capillaries to the lymph spaces which surround every living cell, and there the assimilation occurs. Every cell of the body is practically an island, bathed on every side by lymph, which brings *from* the blood the digested food stuffs (and oxygen as well) and removes *to* the blood stream the waste matters produced by the cells' activities.

Nutrition. All these processes by which food is obtained, prepared, and built into tissues, are grouped together as nutrition and include:

1. Food-getting, selection, and preparation.
2. Digestion which mainly goes on in mouth, stomach, and intestines.
3. Absorption which occurs in the small intestine and stomach, by means of the blood capillaries and lacteals.
4. Assimilation which takes place wherever there is a living cell to be nourished.

Attention should be called to the important part played by osmosis in all these processes. It is concerned in the secretion of all digestive fluids; in the absorption of digested foods through the walls of the capillaries and lacteals, and in the passage of these same foods outward from the capillaries, as lymph.

Demonstration of Digestive Processes. The action of digestive fluids can easily be shown experimentally. Starch paste is put in each of two tubes. Saliva is added to the one and water to the other. Both tubes are kept at about body temperature (98°) for a few hours. If Fehling's test be applied, the tube with the starch and saliva will now yield a sugar test showing the digestive change wrought by the saliva. The tube with no saliva shows no sugar, as the starch remains unchanged.

DIGESTION AND ABSORPTION

	Glands	Secretion	Enzymes	Changes	Absorption
Mouth	Salivary Parotid Sub-lingual Sub-maxillary	Saliva (alkaline)	Ptyalin	Starch to sugar	
Gullet	Mucous	Mucus		Lubricant	
Stomach	Gastric Acid glands	Gastric fluid (acid) Hydrochloric acid	Pepsin Rennin	Proteins to peptones Coagulates casein Stimulates glands	Sugar, Water, Salts, Peptones } by capillaries of gastric vein
Intestine	Intestinal Liver Pancreas	Intestinal fluid Bile (alkaline) Pancreatic fluid (alkaline)	Invertin Trypsin Amylopsin Steapsin	Cane to grape sugar Emulsifies fats Protein to peptones Starch to sugar Fats to fat acids and glycerin	Fats by lacteals Peptones, Salts, Sugars, Water, Fat acids } by mesenteric capillaries

In a similar way digestion of protein may be shown. Use cooked white of egg instead of starch and a solution of pepsin in place of saliva. The egg in the pepsin tube will become soluble after a few hours and will yield a peptone test, showing that it is digested. That in the water remains unchanged and is used merely as a check.

Digestion of fat is shown by using olive oil and a solution of pancreatic fluid. As before, prepare a check tube this time with oil and water only. Shake these two mixtures thoroughly and put in a warm place. In the tube with the pancreatic fluid, the oil will be in a milky emulsion, while that without the digestive fluid shows no change.

Effects similar to these are produced in the digestive organs. Foods are changed into forms which can be absorbed by osmosis into the capillaries which line the stomach and intestine.

An experiment to show the necessity for these digestive changes can be arranged as follows. Fill one diffusion shell with undigested starch and water, and another with a similar mixture of grape sugar. Suspend each in separate dishes of pure water for a few hours. On testing the water no starch will be found, while the sugar will have passed freely through the membrane in the other dish. Starch must be digested into sugar to pass through the absorbing membranes of the body. Other foods are similarly changed in digestion, for a similar reason.

Alcohol and Digestion. Alcohol is often taken with meals or as a medicine, under the impression that it aids digestion. This is not the case. Small amounts of alcohol certainly seem to increase the flow of gastric fluids, but this is in excess of the amount needed to digest the food present at that time, hence is wasted. The glands can normally secrete only a certain amount, therefore, later, when food is to be digested, there is a shortage of fluids available, because of this waste.

Furthermore, after the stomach glands have been over-stimulated by alcohol, they cease to respond so well to the milder stimulation of food. The presence of food ought to provide its proper supply of fluids, but where alcohol has been

used, even in small amounts, food alone is soon unable to provide a sufficient flow. More alcohol is then needed to give the abnormal stimulation and so a habit is formed, and the normal function of the glands is prevented.

Larger amounts of alcohol have a more immediately harmful effect. Water is withdrawn from the food and the proteins are hardened adding to the difficulty of its digestion. Water is also withdrawn from the stomach walls and the lining inflamed and injured. The action of the glands may be permanently reduced and the liver is particularly apt to be overtaxed. Over half the cases of cirrhosis of the liver are traceable to the use of alcohol.

Appetizers, cocktails, and wines with meals, have no beneficial effect and are, instead, distinctly harmful to the digestive processes. Alcoholic medicines should be used with caution and only under the advice of a physician. Many doctors do not approve of their use at all.

COLLATERAL READING

The Body at Work, Gulick, pp. 149–172; *Human Mechanism*, Hough and Sedgwick, pp. 89–131; *Studies in Physiology*, Peabody, pp. 75–166; *Elementary Physiology*, Huxley, pp. 249–303; *Applied Physiology*, Overton, pp. 51–73; *Physiology for Beginners*, Foster and Shore, pp. 128–156; *The Human Body*, Martin, pp. 106–146; *General Physiology*, Eddy, pp. 90–158; *Physiology Textbook*, Colton, pp. 194–231; *Human Body and Health*, Davidson, pp. 76–105; *High School Physiology*, Hughes, pp. 87–142.

SUMMARY TO CHAPTER XL

NUTRITION

1. Digestive Changes.
- a. Making food soluble (for osmosis).
- b. Changing food chemically (for assimilation).
- c. Causes of changes.
  - (1) Mechanical action of teeth and stomach.
  - (2) Chemical action of fluids, enzymes, ferments.

2. Digestive organs (cf. with other animals).
- a. Mouth.
  - (1) Functions in digestion.
    - (a) Mechanical (chewing).
    - (b) Chemical (saliva).

(2) Openings and organs.
  (a) Two nasal openings.
    1. Location.
    2. Method of protection.
    3. Connect with nostrils.
  (b) Two Eustachian tubes.
    1. Location.
    2. Method of protection.
    3. Connect with ears.
  (c) Trachea (relation of epiglottis and tongue).
  (d) Gullet.
  (e) Hard and soft palate.
  (f) Tonsils, adenoids.
(3) Tongue.
  (a) Structure.
  (b) Size.
  (c) Position in mouth.
  (d) Functions.
    1. Taste.
      a. Use for taste.
      b. Location.
    2. Aid in chewing.
    3. Aid in swallowing.
    4. Cleaning teeth.
    5. Speech.
(4) Teeth.
  (a) Parts (make diagram).
    1. Crown.
    2. Neck.
    3. Root.
  (b) Structure.
    1. Enamel.
      a. Structure.
      b. Function.
    2. Dentine.
      a. Structure.
      b. Function.
    3. Pulp region.
      a. Nerves (Why?)
      b. Blood supply (Why?)
  (c) Kinds.
    1. Incisors.
      a. Eight in first set.
      b. Eight in second set.
    2. Canines.
      a. Four in first set.
      b. Four in second set.
    3. Premolars.
      a. None in first set.
      b. Eight in second set.

4. Molars.
   a. Eight in first set.
   b. Twelve in second set.

(5) Glands in general.
   (a) Definition.
   (b) Parts.
      1. Secreting cells.
      2. Ducts.
      3. Blood supply.
      4. Nerve supply.
   (c) Various degrees of complexity.

(6) Salivary glands.
   (a) Parotid (mumps).
      1. Location.
      2. Duct opening.
   (b) Sub-maxillary.
   (c) Sub-lingual.

(7) Saliva.
   (a) Composition.
      1. Alkaline.
      2. Watery.
      3. Three pints daily.
      4. Ptyalin.
   (b) Functions.
      1. Aids in tasting food (solution).
      2. Aids in swallowing.
      3. Stimulates gastric glands (alkali *vs.* aoid).
      4. Ptyalin acts on starches slightly.

(8) Digestive changes in the mouth.
   (a) Food mechanically crushed.
   (b) Moistened for taste and swallowing.
   (c) Some starch changed to sugar.
   (d) Slight absorption of water, sugar, etc.

b. Stomach.
   (1) Location.
   (2) Shape.
   (3) Size.
   (4) Functions.
      (a) Storage.
         1. Why?
         2. What homologous organs.
      (b) Further separation of food particles.
      (c) Digestion of proteins by means of pepsin.
      (d) Coagulation of milk casein.
   (5) Gastric fluid.
      (a) From gastric (simple) glands, acid glands.
      (b) Amount (secretion aided by saliva if well mixed).
      (c) Composition.
         1. Hydrochloric acid.
            a. Neutralizes saliva. b. Aids pepsin.

2. Pepsin.
    a. Changes protein to peptone.
    b. Dissolves connective tissue.
    c. Exposes more surface for digestion.
3. Rennin.
    a. Coagulates milk protein (casein).

(6) Composition of chyme.
    (a) All fats unchanged.
    (b) Most carbohydrates.
        1. Exception.
    (c) Much unchanged protein.
    (d) Unabsorbed peptones, sugars, water, etc.

c. Intestine.
    (1) Pylorus.
        (a) Location.
        (b) Function.
    (2) Parts.
        (a) Small intestine.
        (b) Large intestine.
        (c) Colon.
        (d) Rectum, etc.
        (e) Appendix (lower right side).
    (3) Adaptations for increase of surface (for osmosis for absorption).
        (a) Length.
            1. Twenty-five feet.
            2. Much coiled.
        (b) Walls in-folded.
        (c) Villi (each with blood vessels and lacteals).
        (d) Surface increased five times, twice area of skin.
    (4) Muscular intestinal walls.
        (a) Muscles involuntary.
        (b) Keep food moving along.
        (c) Mix food with fluids and crush it.
        (d) Very important in digestion.
    (5) Glands.
        (a) Intestinal.
            1. Small.
            2. Simple.
            3. Numerous.
            4. In the intestine wall lining.
            5. Secretion.
                a. Alkaline.
                b. Soda carbonate.
                c. Sugar ferment.
            6. Function.
                a. Saponify fats.
                b. Act somewhat on sugar.

(b) Liver.
  1. Largest gland.
  2. Uppermost in viscera.
  3. Over stomach.
  4. Bile.
    a. Thick.
    b. Brown.
    c. One quart daily.
    d. Functions of bile.
      (1) Aids digestion and absorption of fats.
      (2) Stimulates intestinal action.
      (3) Antiseptic action.
  5. General functions of liver.
    a. Excretion of waste.
    b. Secretion of a digestive fluid.
    c. Storage of sugar excess as glycogen (Why?)

(c) Pancreas.
  1. Location.
  2. Fluid.
    a. Abundant.
    b. Alkaline.
    c. Composition.
      (1) Amylopsin.
        (a) Changes starch to soluble sugar.
      (2) Trypsin.
        (a) Changes protein to soluble peptone.
      (3) Steapsin.
        (a) Changes fats to fat acids, soaps, glycerin, emulsions.

3. Demonstration of Digestive processes.

4. Alcohol and digestion.

5. General purpose of digestion.

6. Steps in nutrition.

a. Food-getting, cooking, chewing.
b. Salivary and gastric digestion (further breaking up).
c. Intestinal digestion (most important).
d. Absorption.
  (1) Absorption is the passage of food from digestive tract to blood.
  (2) Way in which absorption may take place.
    (a) Directly into capillaries in stomach and intestine walls.
    (b) Via lymph capillaries (lacteals) in villi.

- (3) Organs of absorption.
  - (a) Gastric capillaries.
    - (1) In stomach walls.
    - (2) Absorb water, peptones, sugar.
    - (3) Empty into general circulation via gastric vein.
  - (b) Intestinal capillaries.
    - (1) In villi.
    - (2) Absorb peptones, sugars, fatty acids, water, salts.
    - (3) Empty into general circulation via mesenteric vein.
  - (c) Lacteals or lymph capillaries.
    - (1) In villi.
    - (2) Absorb emulsified fats.
    - (3) Empty into thoracic duct, then to left juglar vein.

e. Assimilation.

- 1. Definition.
- 2. Course of digested food.
  - (a) Digestive organs.
  - (b) To blood stream (osmosis).
  - (c) Through capillary walls.
  - (d) Into lymph spaces (osmosis).
  - (e) Built into cell substance.
- 3. Blood transports food, etc., to tissues via capillaries.
- 4. Lymph transports foods, etc., to cells after leaving the capillaries.

CHAPTER XLI

RESPIRATION

Vocabulary

Lymph, the liquid part of the blood, in contact with cells.
Pleural membranes, a double membrane covering lungs.
Intermittent, not continuous.
Hæmoglobin, the red, oxygen-carrying part of the blood.

Respiration is the process by which each cell of the body takes in oxygen and gives off carbon dioxide and water. It is tissue oxidation. The *breathing movements*, which renew the air in the lungs, and the *circulation* of blood, which is the means of transportation between lungs and tissues, are merely helps in the real process of respiration which goes on in every cell of the body.

Need of Circulation. These breathing and circulatory processes are required because of the distance of the living cells from the outer air and merely serve to keep the lymph supplied with oxygen and freed from waste. It is between the lymph and each living cell, that respiration actually goes on.

The organs generally associated with respiration, such as the lungs, trachea, etc., are really concerned with supplying oxygen to the blood and removing wastes. No more actual respiration (cell oxidation) goes on in the lungs, than in any other active tissue, but it *is* in the lungs that the hæmoglobin of the blood receives its load of oxygen and unloads its carbon dioxide and water.

Development of Respiration. Respiration in the protozoa takes place by direct contact of each cell with the air dissolved in the water. In the worms the blood circulates in the skin and obtains its oxygen direct from the air. In still higher forms, like crayfish or fish, gills are developed with great extent of surface to absorb the dissolved oxygen in the water. Insects

take their air directly into the tissues and blood by way of their numerous complicated air tubes and so get along with a simple circulation. In the birds and mammals this is reversed; the air comes to one place only (the lungs), while a complex circulation carries the oxygen to all parts of the body.

Organs of Breathing. The organs concerned with breathing motions can be placed in two groups, (1) those concerned with holding and carrying the air, and (2) those which change the size of the chest cavity, causing the air to circulate.

Nose. The air system begins with the nose, which is adapted as an entrance for air,

(1) By the hairs and moist mucus to catch dust.

(2) By the sense of smell to guard against bad air.

(3) By its long moist passages which warm and moisten the air.

The mouth was not intended as a breathing organ except in emergencies, and habitual mouth breathers lose all the advantages mentioned above.

Adenoids. At the back of the nasal cavity, just where it joins the throat, are located the pharyngeal tonsils whose over-enlargement produces a condition commonly called "adenoids." This enlargement partially stops the passage of air from the nose to the throat and thus produces mouth breathing, snoring, and sometimes deafness, due to interference with the Eustachian tubes. The constantly opened mouth and effort to get sufficient air result in a characteristic and disagreeable expression of countenance. If adenoid growth is serious and long continued it may interfere with general bodily health and development. A simple operation will remove such obstructions and ought to be performed whenever adenoids exist.

Trachea. Passing from the nasal cavity to the back of the mouth, the air enters the trachea. This is a large tube which opens into the mouth at the back of the tongue, so that the food passes over it when we swallow. Its upper end is therefore protected by the base of the tongue and by a sort of self-acting lid (epiglottis) which closes when food is passing on its way to the gullet, which is further back in the mouth cavity. The

enlarged upper end of the trachea is the larynx in which are situated the vocal (speech) organs, and which may be seen externally as the "Adam's apple." The walls of the trachea are supported by rings of cartilage, which hold it open for free passage of air.

The trachea and its branches are lined with *cilia* somewhat like those on the paramecium. These are in constant waving motion, and carry up toward the mouth any dust or dirt taken

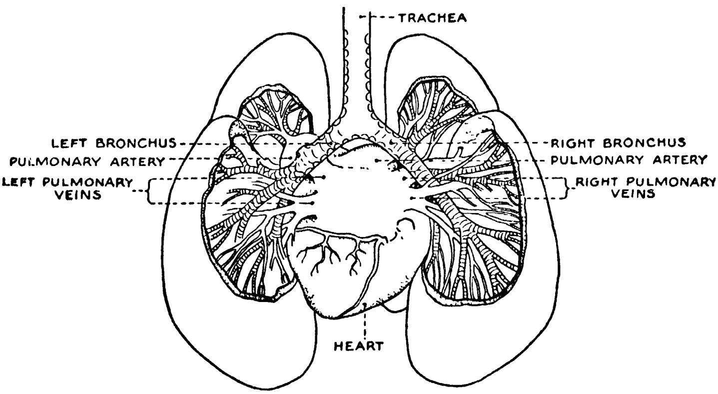


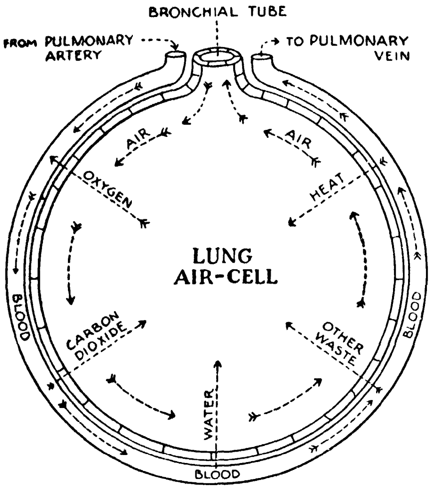
Fig. 155. Structure of lungs and heart. The pulmonary arteries are bringing de-oxygenated blood to the lungs; the pulmonary veins are taking away the blood laden with oxygen.

in with the air. This dust mixed with mucus is removed when we cough or "clear our throat." The nasal passages are also lined with cilia for the same purpose.

With the hand on the larynx, swallow a mouthful of food and notice two things, (1) how it rises and contracts inward to meet the epiglottis, (2) how the very base of the tongue moves back and down over the opening. Both these movements are to allow the food to pass *over* the top of the trachea and *into* the gullet.

Bronchi and Air Cells. At its lower end the trachea divides into two branches (bronchi) one extending to each lung, where they subdivide into countless minute bronchial tubes. These finally terminate in very thin-walled, elastic air cells of which the

lung tissue is largely made. Thus there is provided in one organ (the lungs) enough surface to supply air (via blood) for the needs of the millions of body cells that have no direct access to air. The total area of the air cells in the lungs is about the same as the floor area of a room thirty feet square. This is thirty times the area of the skin outside the body, and would nearly equal the surface area of a balloon ten feet in diameter. It is easy to see why so much area is needed, when we realize the vast number of body cells which are out of direct contact with air, and yet must be supplied with oxygen from the blood which flows through the lungs.



After Colton.

FIG. 156. Diagram to show the exchanges that take place between the blood and the air in the lungs.

The Lungs. The lungs fill most of the body cavity from the shoulders to the diaphragm except the space occupied by the heart and blood vessels. They are very spongy, consisting mainly of the air tubes and cells and a very extensive network of blood vessels and capillaries, all held together by connective tissue and covered on the outside by a double (pleural) membrane. Their shape is the same as the chest cavity, the upper part of which they completely fill. Between them is the heart and below is the diaphragm which is a muscular partition curving upward so that the lower lung surface is sharply concave. The pleural membrane that covers the lungs and lines the chest cavity is constantly moist and permits free motion of the lungs, within the chest, for breathing. Pleurisy is an inflamed condition of these membranes which makes breathing very painful and difficult.

Blood Supply. The pulmonary artery brings the dark (deoxygenated) blood to the lungs. There it divides into an extensive network of capillaries, completely surrounding each air cell. The thin walls of both cell and capillary make easy the osmotic exchange of oxygen from air to blood, and of carbon dioxide and water from blood to air, so that the pulmonary vein returns its blood to the heart, purified and laden with oxygen for the tissues.

Air Capacity. The total capacity of the lungs is about 350 cubic inches of which our ordinary breathing utilizes only about 30. By extra effort we can take in and force out an extra hundred or more, while there is about another hundred cubic inches which we cannot get out at any one breath. When we realize the great importance of oxygen to the tissues these facts ought to be an argument for fresh air, deep breathing, and loose clothing. We use little enough of our lungs, at best, so every effort ought to be made to increase their activity. The one-third of the air which cannot be forced out of the lungs provides for continuous osmosis. Breathing is an intermittent process but the blood's supply of air has to be continuous, hence the need for some air always in the lungs. A reason for deep breathing is to mix as much fresh air with this "residual air" as is possible at each breath.

Breathing Movements. The process of getting air into and out from the lungs is rather complicated and consists of two sets of operations, inspiration (breathing in) and expiration (breathing out) which we somewhat wrongly call the acts of respiration.

Inspiration: The Diaphragm. The chief breathing organ is the *diaphragm*, a muscle (not a mere partition) which extends across the body, curving upward, as a floor to the lung cavity. When its muscles contract it tends to pull down straighter across the body, thus giving the lungs more room, but compressing the abdominal organs beneath it at the same time.

Rib Muscles. Second in importance are muscles between the ribs which lift them up and outward, thus enlarging the lung cavity, and what is more important, bend the elastic rib car-

tilages, which tend to spring the ribs back in place. Another set of rib muscles helps to pull the ribs downward.

Air Pressure. The third important factor in inspiration is the pressure of the outside air which rushes in to occupy the extra space thus provided and by so doing, expands the elastic tissue of the lungs. Inspiration, then, consists of (1) depression of diaphragm and compression of abdominal organs, (2) raising the ribs and bending the rib cartilages, (3) air pressure, expanding the lung tissue.

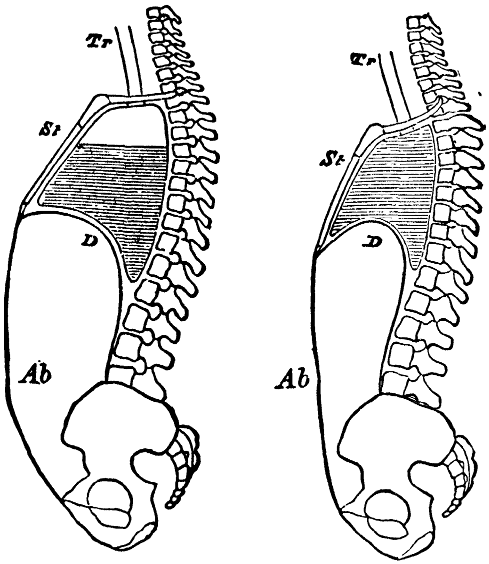


Fig. 157. Diagram to show the changes in the sternum, diaphragm, and abdominal wall in respiration. A, inspiration; B, expiration; *Tr*, trachea; *St*, sternum; *D*, diaphragm; *Ab*, abdominal wall. The shaded part is to indicate the stationary air.

Expiration. Expiration is merely the springing back of the organs that have been compressed by the movements of inspiration. It consists of the following steps: (1) the elastic reaction of the compressed abdominal organs, (2) the springing back of the rib cartilages, (3) the contraction of the elastic lung tissue.

All of these tend to make the lung capacity less and force out the air, against its own pressure. The change of position of the ribs, diaphragm, and abdominal organs can be felt in our own bodies.

Rate of Breathing. This double process takes place from 16 to 24 times per minute, depending upon activity, position, and age. The more oxygen the tissues need, the more rapidly the

lungs have to operate to supply the blood with it, to be carried to the tissues. This is automatically regulated by the amount of oxygen or carbon dioxide which is in the blood. When there is too much carbon dioxide present, it stimulates the respiratory centres in the brain and they produce more rapid breathing. Too much oxygen has the opposite effect.

Air Changes in Breathing. Air contains only about 20 per cent of oxygen. Of this, only about a quarter is absorbed in the lungs by the hæmoglobin of the blood. In the circulation, the hæmoglobin can give out only about one-half the oxygen it contains, so, unless we breathe deeply and keep our breathing apparatus in healthy working order, the tissues may receive too little oxygen. Since oxidation (union of oxygen with tissue) is the only source of life energy, this matter is of very great importance.

Expired air has lost about one-fourth of its oxygen, but receives from the tissues 100 times as much carbon dioxide as it had when taken in, also a large amount of water vapor and heat, together with a very little organic waste matter.

Ventilation. The fact that air in a "close" room becomes unfit to breathe, is due mainly to the excess moisture and heat, and not to the carbon dioxide, or lack of oxygen, as was formerly supposed.

The carbon dioxide in the expired air is produced by the oxygen from the lymph uniting with the carbon of the tissues. The water is produced by oxidation of their hydrogen, and the heat is the result of both oxidation processes. We use annually about 10,000 pounds of air (28.7 pounds per day) from which we take about 650 pounds of oxygen and give off about 730 pounds of carbon dioxide. We breathe out about 9 ounces of water every day, which would make half a pint in liquid form. These figures, while not worth remembering, will give some idea of the amount of work done by the respiratory organs and their importance to our life.

Proper ventilation is concerned, not only with supplying "fresh" air, but with the removal of water vapor, heat, and least important of all, carbon dioxide. Circulation of air in a

room will often relieve breathing conditions, by lowering the body temperature and removing excess water vapor from the vicinity of the body. We usually have oxygen enough in any ordinary air supply, and seldom does the carbon dioxide cause trouble, but very often the temperature and amount of water vapor produce unpleasant and even dangerous results.

"Keeping cool" consists not in *keeping* heat out but in *getting* it out. We get rid of about 100 Calories per hour which is somewhere near the amount of heat given off by four ordinary electric lights. To evaporate a quart of water requires 500 Calories. If the air conditions permit rapid evaporation, our perspiration will remove heat at this rate and keep the body comfortable. If the air already has much moisture in it, evaporation is hindered and our temperature rises—unless heat is eliminated in some other way.

Heat tends to "run down hill." If the air is cooler than our body temperature (98.6 degrees), we lose more or less heat, depending on the difference. If the air is much cooler, we use clothing to hinder the flow of heat from body to air. If the air is warmer, we cannot easily get rid of our bodily heat, and suffer in consequence.

It is thus evident that ventilation has to do with moisture and temperature of the air, even more than with its composition.

A recent report of the New York State Commission on Ventilation proved that temperature and amount of moisture in the air were more important than the proportions of oxygen or carbon dioxide. The following facts are based on this report.

A temperature of 68 degrees or less with sufficient change of air to remove odors without creating drafts, was found to be best. Excess moisture, especially in hot air, causes great discomfort. The heart action and breathing increase and symptoms like fever develop. There is a tendency to closure of the nasal passages and an increase in liability to take cold when going out in cold air.

These same conditions are felt on hot and "humid" days in summer. So much moisture is in the air that the body

cannot get rid of the perspiration readily. This interferes with its heat regulation and discomfort or dangerous overheating may ensue. Extra moisture is less troublesome if the air is cool and the bodily heat is also carried off better if the air is in motion. Hence a fan does promote comfort though not causing any change in the composition of the air.

"Fresh" air is refreshing, not so much because of less carbon dioxide or more oxygen, as because it is usually cooler and less laden with moisture. Hot, moist fresh air is about as bad as stale air from indoors, though really stale or ill-smelling air reduces ability to work and interferes with the appetite.

There is no especial value in extremely cold air except in the treatment of tuberculosis or similar diseases. Air in furnace-heated houses may be too dry; air moisteners are provided to prevent this. In schools and crowded rooms the danger is from too much moisture and too high temperature.

Window ventilation, using muslin screens to prevent drafts, is a satisfactory plan in many cases. In large buildings forced draft has to be used and moisture and temperature must be carefully watched. In homes, windows, doors, and fireplaces provide plenty of fresh air if the temperature, moisture, and circulation are looked after.

Alcohol and Respiration. Alcohol increases the rate of breathing and this might appear useful when great demands are to be made on bodily energy. When the cause of this increased rate is investigated, the conclusion is reversed.

Alcohol relaxes the blood vessels and permits loss of heat through the skin. This loss has to be made good by increased oxidation and the lungs increase their efforts to replace the lost energy. It is like increasing a man's salary a little and then doubling his expenses; his salary is larger, but his condition is worse.

Alcohol interferes with the blood supply to the lungs, causing inflammation, and lowering resistance to pneumonia and congestive diseases.

Continued use affects the oxygen supply of the whole body and may increase connective tissue in the lungs themselves,

thus lowering their efficiency in supplying oxygen. As always, alcohol lowers energy production, and is narcotic in its action, rather than a stimulant as is so often supposed.

COLLATERAL READING

Physiology Textbook, Colton, pp. 105–137; *General Physiology*, Eddy, pp. 312–339; *Applied Physiology*, Overton, pp. 206–219; *Human Mechanism*, Hough and Sedgwick, pp. 162–176; *Human Body and Health*, Davison, pp. 132–162; *Studies in Physiology*, Peabody, pp. 209–231; *Human Body*, Martin, pp. 193–214; *Elementary Physiology*, Huxley, pp. 148–191; *High School Physiology*, Hughes, pp. 179–196.

SUMMARY OF CHAPTER XLI

RESPIRATION

1. Definition.
- a. Respiration is oxidation in the tissues.

2. Aids in respiration.
- a. "Breathing movements" (oxygen from air to blood).
- b. Circulation (oxygen from blood to lymph, to tissues).
- c. Lungs supply osmotic surface for all cells in one place.

3. Development in lower animals.
- a. Protozoa.
  - (1) Each cell in contact with dissolved oxygen.
- b. Worms.
  - (1) Blood in contact with air in skin.
- c. Crayfish.
  - (1) Blood in contact with dissolved air (gills).
- d. Insect.
  - (1) Air brought to blood and tissues in tubes (tracheæ).
- e. Fish.
  - (1) Blood in contact with dissolved air (gills).
- f. Other vertebrates.
  - (1) Blood aërated in lungs.

4. Organs of breathing.
- a. Nose.
  - (1) Adaptations.
    - (a) Hairs (to collect dust).
    - (b) Smell (to detect bad air).
    - (c) Moistening mucous membranes.
- b. Trachea.
  - (1) Structure.
    - (a) Connects mouth and lungs.
    - (b) Opens back of tongue.
    - (c) Stiffened by cartilage.
    - (d) Larynx with vocal organs.

(2) Means of protection.
   (a) Epiglottis.
   (b) Movements of tongue in swallowing.
   (c) Movements of larynx in swallowing.
   (d) Mucous glands and cilia.

c. Bronchi.
   (1) Two branches of trachea to lungs.
   (2) Each with many small branches.
   (3) Air cells at end of branches.

d. Lungs.
   (1) Location.
   (2) Shape.
   (3) Boundaries.
   (4) Structure.
      (a) Air tubes and cells (surface for osmosis).
      (b) Capillaries (blood for transfer).
      (c) Pleural membranes (moist for easy motion).
   (5) Blood supply.
      (a) Pulmonary arteries (dark, de-oxygenated blood).
      (b) Pulmonary veins (lighter, oxygenated blood).
   (6) Capacity.
      (a) 350 cu. in. total.
      (b) 250 cu. in. possibly used.
      (c) 30 cu. in. usually used in ordinary breath.
      (d) 100 cu. in. residual air. (Why?)

5. Breathing movements.

a. Inspiration (increases chest cavity).
   (1) Diaphragm contracts and lowers (*vs.* abdominal organs).
   (2) Rib muscles raise ribs (*vs.* elastic cartilage).
   (3) Air pressure expands cells (*vs.* elastic walls).

b. Expiration (decreases chest cavity).
   (1) Abdominal organs push diaphragm upward.
   (2) Rib cartilages spring back.
   (3) Lung cells contract.

c. Rate.
   (1) 16–24 per minute.
   (2) Depends on age, activity, etc.

6. Air changes in breathing.

	Before inspiration	*After inspiration*
Nitrogen	79 %	79 %
Oxygen	20.96%	16.02%
Carbon dioxide	.04%	4.38%
Water vapor	traces	.60%
Heat	little	much more
Organic impurities	none	considerable.

7. Blood changes in lungs.

a. Just the reverse of the above.
b. Blood gains 4 to 5% oyxgen.
c. Blood loses about same amount carbon dioxide.
d. Blood loses water vapor, heat, organic waste.

8. Ventilation.

a. Large amount of air used.
b. Importance of oxidation.
c. Need for ventilation.
 (1) To supply oxygen.
 (2) To remove heat, water vapor, carbon dioxide.

9. Effect of alcohol on respiration.

CHAPTER XLII

CIRCULATION

Vocabulary

Plasma, liquid portion of blood tissue.
Auricles, upper, receiving chambers of the heart.
Ventricles, lower, sending chambers of the heart.

The function of any circulatory system is **transportation;** the blood is the carrier, the blood vessels are the *roads,* and the heart is the motive power. Digested food is carried from the digestive organs to the tissues, oxygen from the lungs to the tissues, waste matters from the tissues to the lungs, skin, and kidneys, and internal secretions from their glands to places where they are used.

Development of Circulation. A circulatory system is not found in very simple animals like protozoa, sponges, and hydra, because they have so few cells that each can obtain its own food and oxygen and throw off its waste, without the need of a set of organs for carrying them. We do not find a transportation system within our own home, nor even in a small village, for each individual does his own carrying. In larger cities street railways or buses are necessary, while to care for a whole State, numerous railroads and canals are required.

It is the same in animal structure. The simple forms have no circulatory transportation; in higher types there are simple circulatory organs (earthworm). In still more complicated organisms, a heart and blood vessels are required (crayfish), while in the vertebrates, especially birds and mammals with their very highly specialized organs, there is needed a very complete and complex transportation system, in order that each cell may be supplied.

Now we may carry our comparison between cell functions and life on Crusoe's island a step further and find another result of specialization. We will recall the likeness between the one-

elled protozoan and Crusoe. He had to perform for himself all he functions of life, such as preparing his food, making his lothes and building his home. The higher forms of life are ike small communities where one man may build the houses r another specialize in making clothes. This would correspond o the first steps in specialization, as shown by sponges, hydra, tc. As the communities grow, many men work together at one rade to supply all, and this would illustrate the grouping of pecialized cells into tissues, each performing its function for he whole animal (earthworm). Then in larger communities he wants are more numerous, more groups of men specialize in ifferent trades and supply others *at a distance* with their roducts. This is the stage represented by the higher animals, here a transportation (circulatory) system is required. In an this is accomplished by the blood which is kept in motion y the heart, and flows through arteries, veins, and capillaries.

THE FUNCTION OF THE BLOOD

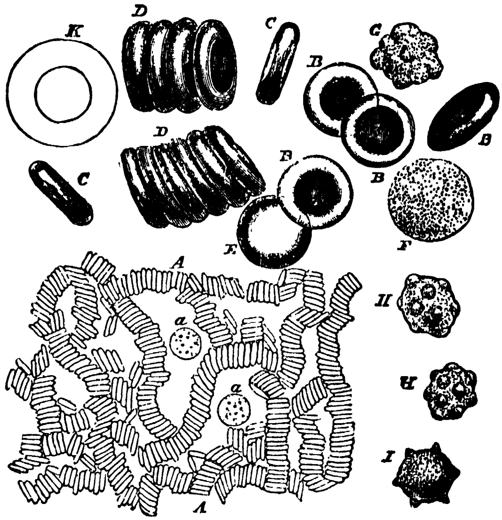
TRANSPORTATION

ransportation of	From	To	For the Purpose of
igested food	Digestive organs	Tissues	Supplying energy Building new tissues Rebuilding used tissues
Vaste	Active tissues	Lungs Skin Kidneys	Removing harmful or useless substances, such as urea, carbon dioxide, water, etc.
xygen	Lungs	Tissues	Releasing energy by oxidation
Ieat	Active tissue	Skin	Equalizing temperature at 98.6 deg.
ecretions	Glands	Various organs	Digestion, etc.

The Blood. The blood is a fluid tissue constituting about $\frac{1}{13}$ f the weight of the body. It consists of a liquid portion called

the plasma, and solid portions called the corpuscles or blood cells. *The plasma* constitutes $\frac{2}{3}$ the bulk of the blood and consists of a liquid (serum) which carries the food and waste products, and a protein substance (fibrinogen), which when exposed to air aids in forming a clot to stop bleeding. *The corpuscles* are of two sorts, red and white; the former much more numerous, thus giving the red color to the blood.

The red corpuscles are minute, disc-shaped, blood cells, so small that ten million can be spread on a square inch, yet so numerous that there are enough in the average body to form a row four times around the equator. Their red color is due to a complex iron compound (hæmoglobin) which carries oxygen from the lungs to the tissues. When laden with oxygen it is bright red, but becomes darker when the oxygen is removed, causing the difference in color of the blood on going *to* and coming *from* the tissues.



From Martin.

FIG. 158. Blood corpuscles. *A*, magnified about 400 diameters. The red corpuscles have arranged themselves in groups; *a*, *a*, colorless corpuscles; *B*, red corpuscles more magnified and seen in focus; *E*, a red corpuscle slightly out of focus. Near the right hand top corner is a red corpuscle seen in three-quarter face, and at *C* one seen edgewise. *F*, *G*, *H*, *I*, white corpuscles highly magnified.

The white corpuscles are really almost colorless and can change their shape much like the amœba. There are probably several kinds and their functions differ, but seem to be concerned in aiding the absorption of fats and in destroying disease germs

in the blood. They are formed in the lymph glands and bone marrow. They have the power to penetrate the capillary walls and wander through the lymph spaces; they collect at wounds and points of infection and oppose the attack of disease germs.

Healing a Wound. In the healing of a cut there are several processes set at work by the blood. First, as the blood oozes out, fibrinogen is exposed to the air and, due to the action of an enzyme in the blood, hardens to fibrin. This entangles the corpuscles, and the clot or scab forms. Then the blood supply is automatically increased to rebuild new tissue, and bring extra white corpuscles on guard to oppose infection. This causes the redness (inflammation) usually noticed. As the fibrin forms, it contracts, causing the puckering of a scar and as fast as new tissue is built, the clot or scab is shed. A slight scratch or blister often lets only the plasma through, while a "black and blue" bruise is in part due to breakage of capillary walls and consequent clotting of blood under the skin.

Changes in Composition of Blood. The composition of the blood is constantly changing as it receives and distributes its various burdens. This is shown in the following table:

Changes in Composition of Blood

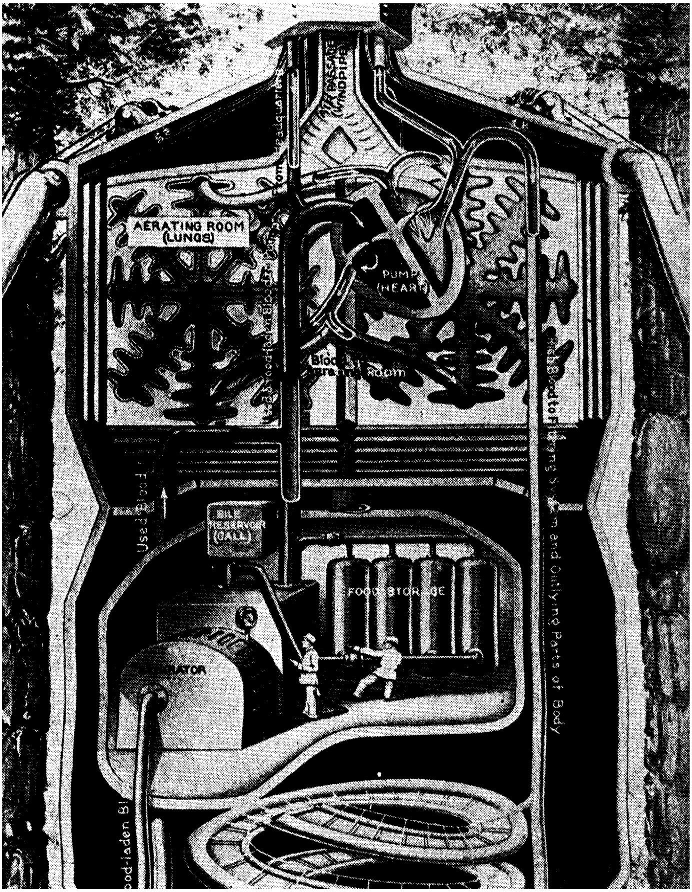
Where	Blood loses	Blood receives
In all active tissues	Materials for growth, repair and energy	Wastes of oxidation Carbon dioxide and water Nitrogenous wastes
In walls of digestive organs	Materials for making digestive fluids and for growth, activity, and repair of the digestive organs	Digested nutrients
In the lungs	Carbon dioxide and water	Oxygen
In the kidneys and skin	Water and urea	Carbon dioxide, etc.

Probably the blood is actually purest when leaving the kidneys, though it is still dark colored, due to lack of oxygen. It

is not correct to speak of "dark blood" as always being "impure blood."

The Heart. The heart is a hollow, cone-shaped muscular organ, located behind the breast bone, between the lungs, nearly on the center line of the body; the point is downward and lies between the fifth and sixth ribs a little to the left. Since the "beat" is strongest near the tip it has given the idea that the whole heart is on the left side, which is not true. The *heart* consists of two entirely separate halves, right and left, *each* of which consists of a thin-walled *auricle,* and a thick muscular *ventricle.* The *auricles* act as reservoirs for the incoming blood and permit a steady flow and their contraction aids the rapid filling of the ventricles. The *ventricles,* by alternate expansion and contraction, force the blood into the arteries and so around the body. Between each auricle and its ventricle are *valves* which allow blood to enter the ventricle but prevent its exit, except by the arteries, and at the base of each artery are valves preventing the blood from flowing back into the ventricles.

Action of Heart. The right auricle receives de-oxygenated blood from the veins through which it has been collected from the whole body. This passes through the valve into the right ventricle, which, when it contracts, forces it to the lungs, via the pulmonary arteries. In the lungs, the blood receives a new load of oxygen, unloads some carbon dioxide and water, and returns via the pulmonary veins to the left auricle. From here it passes through the valves into the left ventricle and is thence forced out through the aorta to all parts of the body. The ventricles contract and expand together so there are two waves of blood sent out at each beat, one to the lungs and one to the general circulation. While the ventricles are contracting and forcing *out* their blood, both auricles have been filling so there is no stop in the flow. The heart is more powerful, in proportion to its weight, than a locomotive: more accurate in its action, than a watch. It never can rest and it repairs its own wear. A truly wonderful organ, but one that we take for granted and often abuse by overwork or improper habits.



From Compton's "Pictured Encyclopedia"—F. E. Compton & Co.

FIG. 159. The Purifying, Separating, and Storage Rooms. The used blood flows into the right side of the heart, then is pumped into the aërating system (the lungs.) The purified blood comes back to the heart, this time to the left side, and is distributed over the body. This diagrammatic picture shows the liver storing up some food taken from the blood, and also removing some impurities.

Rate of Beat. The rate of heart beat is normally 72 times per minute in man; 80, in women; much higher in young children and in very old persons, reaching the average at about twenty years of age. Naturally, the amount of blood needed is affected by exercise, temperature, food, excitement, pain, etc., and so all these automatically change the rate of heart beat. When we run upstairs (a bad habit, by the way) we use more energy, hence oxidize more tissue, hence need more oxygen to be brought by the blood and produce more waste, which must be carried off.

With the body at rest the heart pumps about five pints of blood per minute. Walking raises the amount to twenty pints and running upstairs increases it to thirty-five pints in the same time.

The total amount of blood in the body is about 8.8 pints, hence the left ventricle handles all the blood about four times per minute. When we realize that the actual muscle used in the ventricle weighs only about a quarter of a pound and is only half an inch thick, we can get some idea of the efficiency of the heart as a pump.

Fear, anger, worry, and mental states in general also affect the action of the heart and influence other bodily functions. If the heart is to operate properly, the state of mind ought to be carefully controlled.

Blood Vessels. *Arteries.* All the vessels that carry blood away from the heart are *arteries* regardless of whether they carry red (oxygenated) or dark (de-oxygenated) blood. Arteries have elastic muscular walls, and very smooth linings. Their function is to assist and to regulate blood flow. Since they are elastic they expand when blood is forced into them, and as the valves prevent it from returning to the heart, their elastic contraction carries on the pressure of the ventricles clear to the capillaries.

If it were not for this elasticity, which is greatest in the large arteries, the circulation would be unsteady and the arteries themselves in danger of bursting under the sudden strain, when the ventricles contract. In "hardening of the arteries" this elasticity is lost and produces serious results.

In general the arteries are protected by location beneath

thick muscles, but at the wrist and neck some large ones come near the surface. Their elastic wave of expansion can be felt, and is known as the *pulse.*

The pulse is most easily felt at the wrist. Place the finger tips on top of the wrist, on the thumb side and press gently into the groove between the outer arm-bone and the tendon or "cord" next to it.

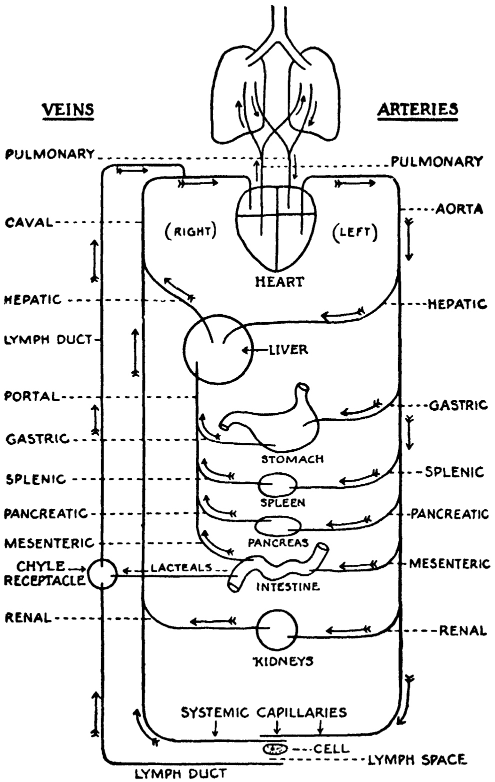


FIG. 160. Diagram to show general plan of circulation of the blood and lymph.

The throb of the pulse can be plainly felt and its rate counted. Count your own or a friend's pulse rate and see how it compares with normal rate for your age. Do a few minutes of active exercise and count the pulse again, noting the change in rate. It is a good plan to become accustomed to finding and counting the pulse rate, as sometimes it is necessary to be done in emergencies.

The muscles in the artery walls perform the important function of regulating the amount of blood that reaches a given organ. By a complicated system of nerve control, these muscles expand when more blood is required and contract when the supply is not needed.

Capillaries. As the arteries leave the heart they divide again and again, becoming smaller and thinner walled till they develop into microscopic tubes with a wall of only one layer of cells. These tiny blood vessels are the capillaries ("hair like") and are so numerous that they reach every living tissue of the body. Their large area and thin walls permit osmosis to go on readily. It is by way of osmosis from the capillaries that food actually reaches the body cells. Absorption of food in the digestive tract and excretion of waste from tissues in lungs, skin, and kidneys are also by means of these very important blood vessels. Capillaries in the web of a frog's foot can be seen under the microscope and the flow of corpuscles is easily visible.

Veins. On leaving an organ the capillaries unite to form veins, which grow larger as they approach the heart, and always carry blood *toward* this organ. Their walls are thinner than the arteries, having little elastic or muscular tissue. Many of the larger ones are provided with cup-like valves to prevent backward flow of blood. Veins are often just beneath the skin and can be easily seen on the back of the hand where the dark color of their blood is conspicuous; enlargements show the location of the valves. Veins have no pulse wave and the blood pressure is lower than in the arteries. Except for the pulmonary veins, their blood is dark (de-oxygenated) as compared with the redder, arterial blood. However, this is of little use in deciding whether a wound has cut a vein or artery, as on exposure to air, blood absorbs oxygen and brightens in color.

Bleeding from an artery, if large enough to be serious, is in pulse-like spurts, while the flow from veins is steady. This and the location of the wound are the best means of distinguishing the source of blood flow.

Lymph Circulation. A part of the blood plasma that diffuses through the capillary walls into the spaces between the cells does not return to the capillaries directly but is collected into the lymph capillaries.

These tiny tubes connect all the lymph spaces together and unite to form the lymph veins which eventually join to empty

into the blood stream near the jugular (neck) veins. Thus, a part of the plasma, instead of following the usual route (artery—capillary—vein) may return as follows, artery—capillary—lymph space—lymph capillary—lymph vein—true vein. It is in the form of this lymph that the blood actually nourishes the tissues and the lymphatic circulation is just as necessary as that of the blood as a whole.

Each cell of the body is practically an island surrounded by lymph. This lymph has passed, by osmosis, through the

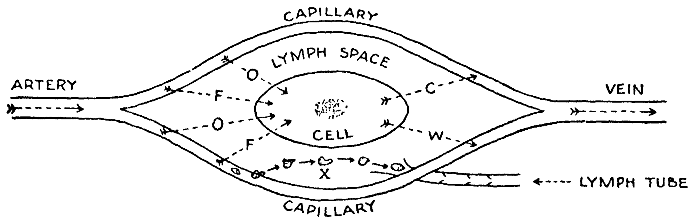


FIG. 161. Diagram to show relation between blood, lymph and cell. The relative size of the lymph space is much exaggerated. "O-O," oxygen; "F-F," digested food; "C," carbon dioxide; "W," other waste matter; "X," white corpuscles.

capillary walls, bearing in solution the digested food stuffs from the alimentary tract, and oxygen from the lungs.

These the cell uses in its life activities and throws off carbon dioxide, water, and other wastes into the lymph, and thence into the blood of the vein capillaries.

White corpuscles may pass through the walls of the capillaries and thus get into the lymph spaces, from whence they may pass out with the returning lymph, by way of the lymph capillaries, to rejoin the blood, through the lymph system.

The lymph thus stands between the blood stream in the capillaries, and the living cells of the body. The blood leaves the heart by one route, the arteries, and returns part way by two, namely, the veins and the lymph system. These unite before reaching the heart again.

Ductless Glands. There are in various parts of the body, glands which have no ducts, but which discharge their products directly into the blood. These products are called internal

secretions. The action of these glands is not thoroughly understood, but they supply the blood stream with substances called *hormones.* These are chemical messengers, carried to various organs by the blood, regulating or coördinating their action. A good example of a ductless gland is the *thyroid gland* consisting of two dark colored portions located just below the "Adam's Apple." The hormone secreted by this gland regulate the rate of cell activity and energy release. A deficiency in thyroid secretion produces a type of idiocy known as "cretinism." This can sometimes be remedied by feeding such patients an extract from the thyroid glands of sheep or other animals. On the other hand, an abnormal thyroid causes the enlargement of the neck known as goiter which may produce serious or fatal results.

The *pituitary gland* is a small organ little larger than a pea, located beneath the brain. It consists of two parts, from one of which a hormone is secreted, which regulates the growth of the skeleton and the size of the body. Giants and dwarfs, such as we sometimes see at circuses, owe their unusual stature to a greater or less activity of this tiny gland.

Near the kidneys are located the *adrenal glands* whose hormone affects blood flow and pressure and also releases sugar stored in the liver for immediate use in energy production. In this way the adrenals are valuable in emergencies when extra energy is needed to escape danger. Their hormone, discharged into the blood, reaches the liver and causes that gland to release its stored sugar which provides the energy for the critical moment.

The *pancreas* although having a duct and an important external secretion, has an internal secretion also. This contains a hormone which enables the liver to store up sugar, and also regulates its oxidation in the muscles. When a person lacks this hormone, he cannot store or oxidize sugar which then accumulates in the body or is thrown off by the kidneys. This condition is the disease called diabetes and can be relieved by injection of the hormone obtained from the pancreas of sheep.

The following table summarizes the activities of some of the internal secretions of the body:

SOME GLANDS OF INTERNAL SECRETION

Gland	Hormone	Location	Function
Thyroid	Thyroxin	Neck, near Adam's apple	Regulates growth and repair Lack causes cretinism Excess causes goiter
Pituitary	Tethelin	Under front of brain in mid-line	Regulates growth in size and proportion of body parts
Adrenals	Adrenalin	Above each kidney	Regulates blood flow and pressure. Releases sugar for emergency oxidation.
Pancreas	Insulin	Near junction of stomach and intestine	Regulates sugar absorption and oxidation Lack causes diabetes.
Thymus		Back of breast bone	Essential to early growth
Pineal		Near pituitary	Regulates early growth
Parathyroid		Near thyroid	Stabilizes sympathetic nervous system

Alcohol and Circulation. Blood flow is regulated by the nerves that control the arteries and heart. Alcohol tends to paralyze these nerves, the blood vessels relax, blood is allowed to flow more freely, the heart works harder to meet the strain and appears to be "stimulated."

What really happens is that the control centres are out of business and the circulatory organs are "running away." You might as well talk of "stimulating" an engine by taking off the governor.

This relaxing of the capillaries allows more blood to reach the skin. This permits abnormal loss of heat, though the skin feels warmer due to the blood which is bringing the heat from within.

Permanent reddening of the skin and mucous membranes

is another result. The former detracts from one's appearance and the latter reduces resistance to colds and other diseases. Alcohol injures the white corpuscles, and thus lowers resistance in another way. Excessive use may produce hardening of the arteries or fatty degeneration of the heart muscle.

COLLATERAL READING

Studies in Physiology, Peabody, pp. 117–158; *Elementary Physiology*, Huxley, pp. 119–147; *Applied Physiology*, Overton, pp. 156–191; *Physiology for Beginners*, Foster and Shore, pp. 78–107; *General Physiology*, Eddy, pp. 159–203; *Physiology Textbook*, Colton, pp. 48–104; *Human Body and Health*, Davison, pp. 106–130; *High School Physiology*, Hughes, pp. 154–178.

SUMMARY OF CHAPTER XLII

CIRCULATION

1. Functions of circulatory system.
- a. Transportation of food from digestive organs to tissues.
- b. Transportation of oxygen from lungs to tissues.
- c. Transportation of waste from tissues to lungs and kidneys.

2. Reasons for varying degrees of development of circulatory system.

3. Blood.
- a. Composition.
  - (1) Plasma (two-thirds bulk).
    - (a) Serum (carrier of food and waste).
    - (b) Fibrinogen (aids in forming clot).
  - (2) Corpuscles (one-third bulk).
    - (a) Red.
      - 1. Disc-shaped cells.
      - 2. Minute.
      - 3. Numerous.
      - 4. Contain hæmoglobin (oxygen carrier).
    - (b) White.
      - 1. Amœboid.
      - 2. Can penetrate tissues.
      - 3. Destroy germs.
      - 4. Help absorb fats.
- b. Blood and the healing of wounds.
  - (1) Fibrinogen exposed, fibrin forms clot.
  - (2) White corpuscles brought by extra blood supply.
  - (3) New tissue built and scar forms.
- c. Changes in blood composition. (See tabulation in text.)

4. Heart.
- a. Shape (hollow cone-shaped muscle).
- b. Location (between lungs, behind breast bone, point to left).
- c. Structure.
  - (1) Auricles.
    - (a) Thin-walled. (b) Act as reservoirs.
    - (c) Cause steady flow.
  - (2) Ventricles.
    - (a) Thick-walled. (b) Muscular.
    - (c) Propel the blood.
  - (3) Valves.
    - (a) At base of arteries and between auricles and ventricles.
    - (b) Prevent back flow of blood.
- d. Action.
  - (1) De-oxygenated blood from body, via caval veins flows to right auricle, right ventricle, pulmonary artery, lungs.
  - (2) Oxygenated blood from lungs returns via pulmonary vein to left auricle, left ventricle, aorta, general body circulation.
- e. Rate of beat.
  - (1) 72–80 beats per minute.
  - (2) Dependent on age, activity, state of mind, etc.

5. Arteries.
- a. Carry blood *from* the heart.
- b. Structure.
  - (1) Smooth lining (to permit easy blood flow).
  - (2) Elastic tissue (to allow for pressure and propel blood).
  - (3) Muscular tissue (to regulate blood supply).
  - (4) Deeply placed (for protection).
  - (5) Thick-walled. (6) Pulse.

6. Veins.
- a. Carry blood *toward* the heart.
- b. Structure.
  - (1) Smooth lining.
  - (2) Pocket valves (to prevent back flow).
  - (3) Thin-walled.
  - (4) Little elastic or muscle tissue.
  - (5) Placed nearer the surface.
  - (6) No pulse wave.

7. Capillaries.
- a. Connect arteries and veins.
- b. Very thin, small, and numerous.
- c. Provide surface for osmosis in nutrition, respiration, and excretion.

8. Lymph circulation.
- a. Function. b. Route.

9. Ductless glands.

10. Alcohol and circulation.

CHAPTER XLIII

EXCRETION

Vocabulary

Urine, the liquid excreted by the kidneys.
Urea, a nitrogenous substance in the urine, waste.
Excretion, throwing off of waste products.
Secretion, production of useful substance by glands.

All the activities of the body require energy, whether in the muscles, nerves, or glands. Energy implies oxidation, and oxidation produces waste products which must be removed. The main wastes of the body are carbon dioxide and water and nitrogenous compounds (mainly urea) together with some mineral salts, chiefly sodium chloride (common salt).

Organs of Excretion. The most important organs of excretion are the kidneys and lungs; then come the intestine, liver, and last, the skin which has other more important functions.

Kidneys. The kidneys are bean-shaped glands located near the spine at the "small of the back." They are about two by four inches in size and are usually imbedded in fat. Their internal structure is too complicated for description here, but is perfectly fitted for removing from the blood, urea, uric acid, mineral salts, and water. Their blood supply is very large and under high pressure, which is important in removal of these wastes. As it leaves the kidneys in the renal veins, the blood is actually purer than anywhere else in the body though it may still be dark in color, due to lack of oxygen.

The ducts from the kidneys lead to the bladder where the urine (which is constantly being excreted) is stored. The amount of urine is usually about three pounds per day and the nitrogenous wastes which it contains are of such character that if incompletely removed, very serious diseases are sure to result.

Exposure to cold, drinking large quantities of water, and excess of protein food all tend to increase the amount of urine.

As some of the waste matters are not very soluble, it is a good thing to drink plenty of water to keep the kidneys well washed out. As a rule we drink too little water rather than too much.

The Lungs. The lungs are used as organs of excretion as well as for the supply of oxygen, their wastes being carbon dioxide mainly, together with considerable water and very little nitrogenous matter.

The Liver and Intestines. The liver and intestines are both concerned with the removal of bile, a part of which is waste matter, and the intestines also remove the unused food refuse, which, however is not strictly excretion. This food refuse, if retained too long in the intestine, may cause trouble. Regular habits of bowel movement should be established.

The Skin. The skin excretes considerable water and only one per cent of solid matter, mainly salts. The chief function of perspiration is to regulate the temperature of the body.

Structure. While not primarily an organ of excretion, the structure and functions of the skin may be discussed at this point. The human skin is a much thicker and more important organ than we usually suppose. If tanned it would make leather as thick as the pig-skin cover of a foot ball.

It consists of an outer portion (epidermis) composed of many layers of cells. The outermost are dead, horny scales; the inner ones, more active and larger. Its function is mainly protective and the outer scales are constantly being rubbed off and replaced by new from beneath. Where subject to much friction or pressure the epidermis may grow to over a hundred cell layers in thickness, producing the familiar callouses of hands and feet.

Hair, nails, and color cells are developed from the epidermal layer in man. Scales, feathers, and claws are modified forms found in other animals.

Beneath the epidermis is a thicker layer (the dermis) consisting of tough fibrous connective tissue, richly supplied with blood and lymph vessels, nerves, sweat glands, and oil glands.

Functions of the Skin. These include:

1. Protection from germ attack and mechanical injury.
2. Protection of inner tissues from drying. The skin, aided

by the oil glands, is nearly water proof, neither absorbing nor letting out much moisture, except at the sweat pores.

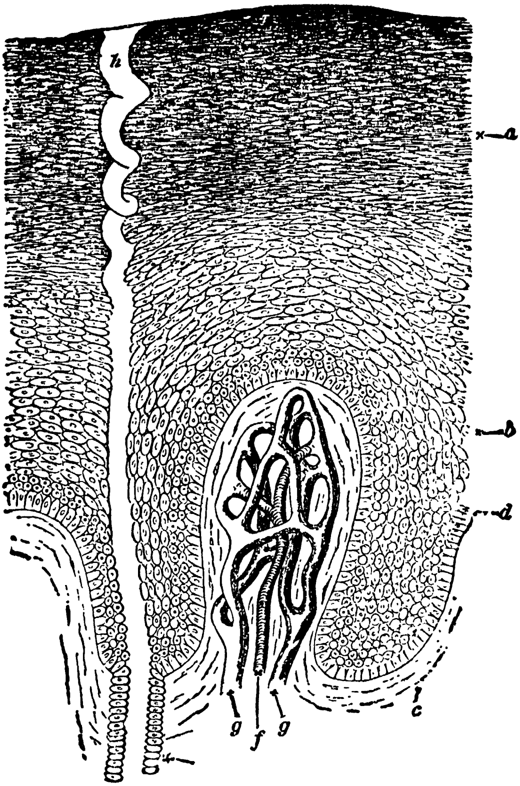


FIG. 162. A section through the epidermis, somewhat diagrammatic, highly magnified. Below is seen a papilla of the dermis, with its artery, *f*, and veins, *g*, *g*; *a*, the horny layer of the epidermis; *b*, the *rete mucosum* or Malpighian layer; *d*, the layer of columnar epidermic cells in immediate contact with the dermis; *h*, the duct of a sweat-gland.

3. It is the location of most of our nerves of touch.
4. Excretion of sweat as a waste matter.
5. Excretion of sweat to regulate the temperature of the body.

This last statement needs explanation. Birds and mammals are the only animals whose temperature does not change with

that of their surroundings. The rate of oxidation and hence the production of heat varies as well as the outside temperature. This means that a heat-regulating device is required.

To evaporate water requires heat, therefore if moisture is excreted on the surface of the skin, the body's heat is taken up in evaporating it and consequently the skin is cooled. The blood supply to the skin is great the surface exposed for evaporation is also large, and so by the use of the body heat to vaporize (dry off) the perspiration, the blood, and hence the whole body, is cooled.

The greater our activity or the warmer the surrounding air, the larger is the amount of perspiration, and hence the greater cooling effect.

A complex system of nerve control governs the blood supply and gland activity of the skin, so that, mainly by its means our temperature is kept at 98.6 degrees. The importance of this function of the skin is seen when we realize that a temperature of eight degrees either above or below the normal is usually fatal.

Alcohol and Excretion. Alcohol interferes with normal oxidation and tends to increase uric acid and other wastes. This may result in overworking the kidneys. Excessive use of alcohol makes one more susceptible to rheumatism, Bright's disease, and fatty degeneration of the kidneys.

As stated before, one of the immediate effects of even small amounts of alcohol is the increase of blood supply to the skin. This causes redness, which develops into permanent inflammation, if alcohol is regularly used. Blotches and pimples may also result from over accumulation of wastes in the skin. Heat regulation is also interfered with.

The effects of alcohol on the lungs and liver are mentioned elsewhere.

COLLATERAL READING

Physiology Textbook, Colton, p. 381; *General Physiology*, Eddy, pp. 352–373; *Applied Physiology*, Overton, pp. 248–255; *Human Mechanism*, Hough and Sedgwick, pp. 177–186; *Human Body and Health*, Davison, pp. 175–190; *Studies in Physiology*, Peabody, pp. 232–252; *Human Body*, Martin, pp. 215–229; *Elementary Physiology*, Huxley, pp. 193–247; *High School Physiology*, Hughes, pp. 197–213.

SUMMARY OF CHAPTER XLIII

EXCRETION

1. Waste.

a. Source.
  (1) Oxidation in tissues.
b. Kind.
  (1) Carbon dioxide.
  (2) Water.
  (3) Nitrogenous compounds.
  (4) Salts.

2. Organs of Excretion.

a. Kidneys.
  (1) Location (small of back, near spine).
  (2) Size (two by four inches, bean-shaped).
  (3) Blood supply large and under high pressure.
  (4) Ducts connecting with bladder.
  (5) Remove water, urea, salts, etc. (3 lb. daily).
b. Lungs.
  (1) Remove carbon dioxide, water, little nitrogenous waste.
c. Liver and intestines.
  (1) Remove bile and unused food stuff.
d. Skin.
  (1) Removes water, salts, etc. (not primarily excretory).
  (2) Structure.
    (a) Epidermis.
      1. Scale-like cells.
      2. Loose.
      3. Protective.
      4. Callouses.
      5. Modified as hair, nails, claws, horns, etc.
    (b) Dermis.
      1. Fibrous cells.
      2. Many blood and lymph capillaries.
      3. Nerves.
      4. Sweat and oil glands.
  (3) Functions.
    (a) Protection from germs, injuries, water, drying.
    (b) Sensation.
    (c) Excretion.
    (d) Temperature regulation.
      1. Sweat excreted.
      2. Evaporated by body heat.
      3. Body therefore cooled.

3. Alcohol and Excretion.

CHAPTER XLIV

THE NERVOUS SYSTEM

Vocabulary

Convolutions, irregular grooves in the surface of the **cerebrum.**
Voluntary, under control of the will.
Harmonize, to coördinate, to make to work together.
Inhibit, to restrain or prevent.

The brain is the one organ which in man is capable of greater development than in any other animal. No amount of training will enable us to compete with the fish, bird, dog, or snake in speed, strength, locomotion, or keenness of sense. Practically every animal excels man in some way and the one thing that makes man their superior is his greater intelligence, which means greater brain development.

Despite this, we often devote more attention to other lines, in which we cannot hope for really useful success, and leave to very indifferent care the training of our one source of superiority.

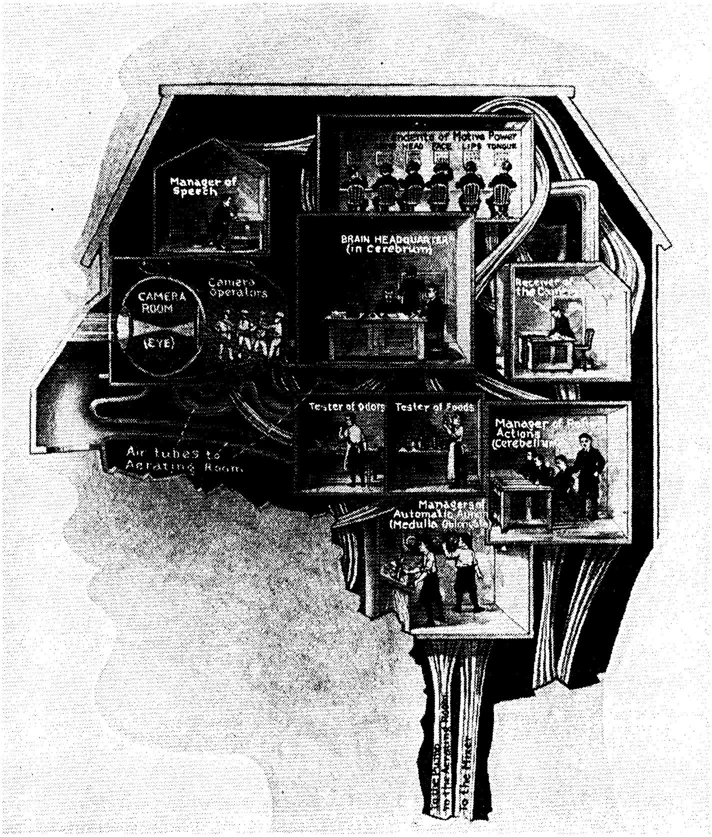
While we cannot deal with the structure of the brain in detail, the need of some controlling organ to regulate the complicated functions of any animal's body is very apparent.

Not only does the nervous system control the other activities of the body, but it puts us in touch with our environment, through the medium of the sense organs.

The more highly the nervous system is developed and trained, the better we can cope with our surroundings. We have only to consider the loss of hearing or sight, to realize how much we depend on these senses for happiness, comfort, or even life itself.

Structure of the Brain. The brain consists of three general regions, the cerebrum, the cerebellum, and the spinal bulb. Connected with it are the spinal cord and nerves which together with the brain compose the *central nervous system.*

Cerebrum. The cerebrum constitutes about nine-tenths of the brain; it occupies the upper part of the skull and is divided into two halves or hemispheres. Its surface is deeply folded in ir-



From Compton's "Pictured Encyclopedia"—F. E. Compton & Co.

FIG. 163. The Control Station of the Body. This diagrammatic picture shows the brain as the executive branch of a big business, with the division into departments. In the Headquarters Office sits the General Manager—the person's Conscious Self. From this office there are lines of connection with the other departments and the Assistants.

regular grooves (convolutions) and consists of gray nerve cells. Internally the bulk of its tissue is made up of white nerve fibres

Details of the vastly complex structure by which each cell is cross connected to thousands of others, the tree-like branching of the nerves, the grouping in larger fibres and passage from one part to another of the brain and spinal cord, all will have to be omitted. We know that it is the most complicated organ in the world but we are far from a complete understanding of its structure, much less its mode of operation.

Experiment and disease have shown that the cerebrum is the centre of intelligence, thought, memory, will, and the emotions. It is the region of conscious sensation, by which we perceive all that goes on about us, and in it arise the impulses which produce all our voluntary motions.

The brain is sometimes called "the organ of the mind" but it does not secrete thought, as the liver secretes bile.

It is the organ through which our mental, moral and spiritual natures do their work, but the chemical changes of the brain, marvelous as they are, are not all there is to intellect or character. A higher Source has to be sought for that.

Cerebellum. The cerebellum is situated behind and below the cerebrum, is much smaller, is not divided, and has shallower and more regular convolutions. Its function is mainly to regulate and harmonize (coördinate) muscular action. This is very essential. When we run, or skate, or walk, or swim, or throw a ball, we use nearly all of the five hundred muscles of our body. Each muscle fibre is controlled by a nerve; each nerve impulse must reach its muscle at the proper instant. When we stop to analyze the simplest act and think how many muscles are made to work together in perfect harmony, we realize how important is this coördination of muscular action by the cerebellum. Without it, though the cerebrum might originate the impulse to do a certain act, no regulated useful motion could result.

Spinal Bulb. The spinal bulb is really an enlargement of the spinal cord but is within the skull and closely attached to the cerebellum. It is about the size of a walnut and is located at the extreme base of the brain.

The spinal bulb is the centre of control of respiration, circula-

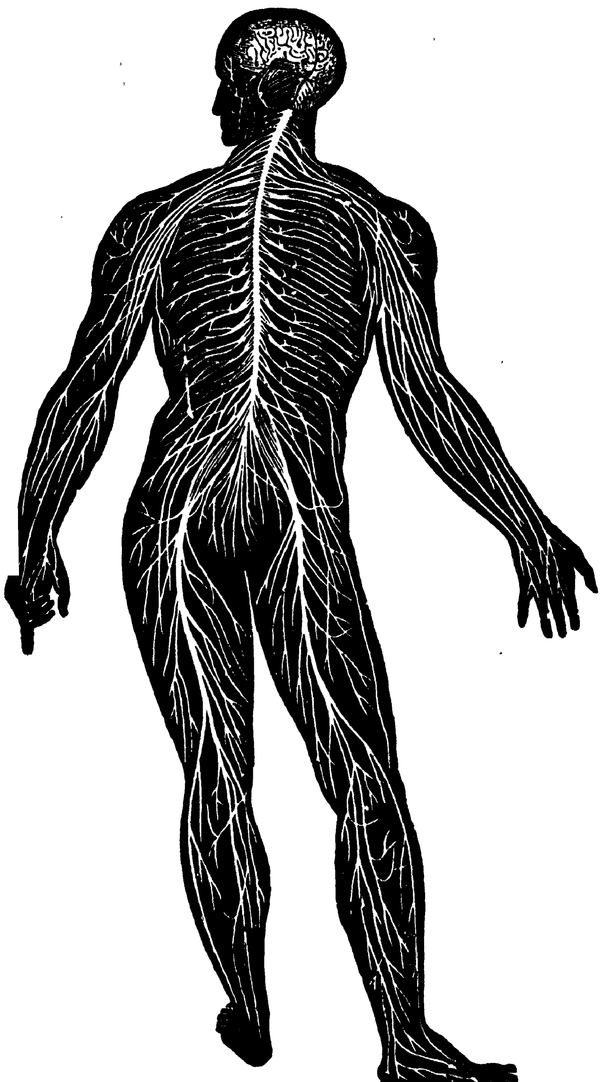


Fig. 164. Diagram illustrating the general arrangement of the nervous system.

tion, secretion, movements of digestive organs and of swallowing, as well as other similar automatic and unconscious activities. Naturally, death follows injury to this vitally important part of the brain, though severe damage to the other parts may not be fatal.

Spinal Cord. The spinal cord extends from the medulla through the protective bony arch of each vertebra, down almost the whole length of the spine, and from it branch the nerves that supply all parts of the body, except those which spring from the brain directly. The spinal cord is not merely a large nerve trunk, however, but is the centre of many involuntary muscular actions (reflex actions) of the body and limbs. If we touch a hot stove, we do not have to *think* to remove our hands. Voluntary action would take too long and injury would result before the brain could have time to act, so most of such reflex actions are centered in the spinal cord and operate automatically but not *unconsciously* as do the motions of the internal organs controlled by the medulla.

The spinal cord, then, has two functions:

(1) A connecting trunk between brain and other nerves.

(2) The centre of reflex action.

Nerves. If all the other tissues of the body were dissolved away its outline would still be preserved by the network of nerves that would remain. Fibres made up of nerve cells reach every part of the body: brain, spinal cord, ganglia, and nerves are composed of these nerve cells.

Nerve cells are more complicated and in some cases larger than the other cells of the body: they are called *neurons* and consist of a cell body from which extend projections called *processes.* There are usually several short branching processes, called *dendrites,* and one long one called the *axon.* Some cells have two or more axones.

The cell bodies are located mainly in the gray matter of the brain, the inner portion of the spinal cord, and in various scattered masses, called plexuses. The axones form the nerve fibres which largely compose the inside of the brain (white matter), the outside of the spinal cord, and the nerves

themselves, which are bundles of axones enclosed in a sort of sheath.

The dendrites of one cell are closely in contact with dendrites from other cells and this seems to provide the means by which nerve impulses are transmitted from one cell to another. Axones may be long, some extending from the spinal cord out to the toes or fingers; others, connecting different parts of the brain or spinal cord, are very short. At their ends they usually divide into brush-like branches where they connect with a sense organ or muscle cell, or with dendrites of other neurons.

Sensory and Motor Fibres. Some neurons carry impulses inward, from sense organs to the brain and are called *sensory* or *afferent* fibres. Others convey impulses from brain to muscle and are called *motor* or *efferent* fibres. In general, the former produce what we call sensation and the latter cause motion. There are also neurons that connect motor and sensory cells.

If we see a pencil and then pick it up the process is something like this. The light reflected from the pencil affects the nerve endings in certain cells of the eye. These convey the impulse along their axones to the sight centre of the brain, whose dendrites pass it on to other cells and we "see" the pencil.

Dendrites from these cells also communicate with motor neurons connected with the arm muscles and we move these muscles by impulses sent

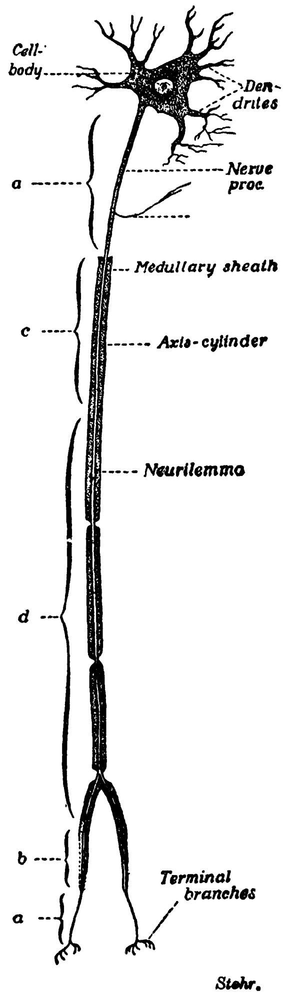
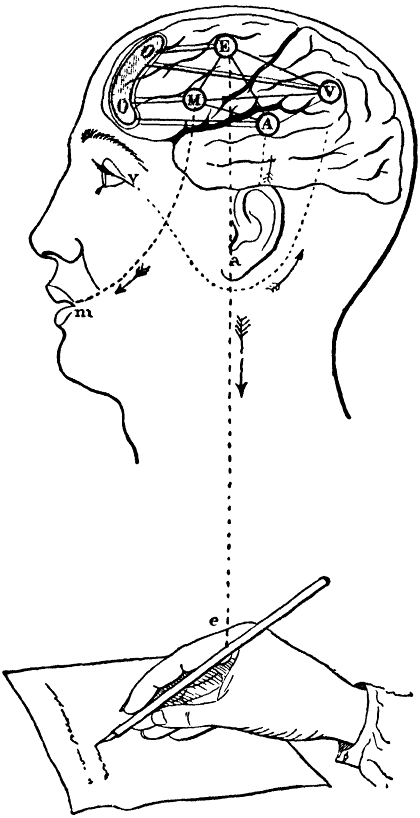


FIG. 165. Diagram of a neuron.

along their axones to the muscle fibres. Figure 166 on this page shows several possible connections which might thus be made. Since every cell of the brain is in touch with almost every other, the number of possible connections is countless.



From Kellogg.

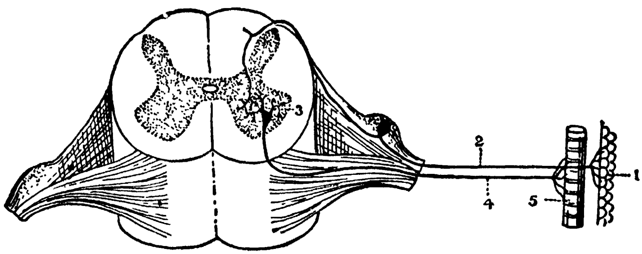
FIG. 166. Diagram showing relation of various brain centres. *A*, centre for hearing; *V*, centre for sight; *M*, speech-motor centre; *E*, hand-motor centre; *O*, *O*, thought centre.

Nerve "impulses" are often compared to electrical currents but it must be remembered that their nature is not understood. The nerve current is certainly much slower than electricity, being about 200 miles per hour whereas electricity travels at the rate of 186,000 miles *per second.* The comparison of the brain to a telephone "central" where incoming and outgoing connections are made, is a good one as far as it goes, but much happens in the brain besides mere cross connection.

Reflex Action. Picking up the pencil was an act controlled by the brain; we saw the pencil and decided to pick it up. Such actions are called voluntary because regulated by the will. There is another important class of actions which are not directed by the brain but centre in the spinal cord. They usually happen more quickly than voluntary actions.

For example, if you touch a hot object, you pull your hand back instantly, without "thinking" about it at all. In fact the motion preceded the feeling of the burn. The nerve route in this case was from the branches of a sensory axon in the finger to the spinal cord. There the dendrites of the afferent cell connected with those of an efferent or motor cell, the impulse went out along the motor axon, and the muscles moved the finger out of danger.

All this happened without waiting for brain action. *After* you jerked your hand away, other nerve fibres in the cord communicated with the brain and you "felt" the hurt. If you had waited for voluntary action, much more damage would have been done. The *reflex arc*, as this nerve route is called, is illustrated in Fig. 167. Here an impulse at (1) is passed



From Kellogg.

FIG. 167. Diagram of simple reflex arc. 1, surface of sense organ; 2, sensory nerve; 3, motor nerve cell in spinal cord; 4, motor nerve; 5, muscle.

on to the inner part of the spinal cord by axon (2). Then it is communicated to the dendrites of the motor cell (3) and passes via the motor axon (4) to the muscle (5), where motion is produced.

Sneezing, coughing, winking, laughing when tickled, or jumping when surprised by sudden sights or sounds, are all reflex actions. Most of them save the body from injury by getting a motor response quicker than would come by voluntary action.

Sympathetic System. On each side of the spinal column but *inside* the body cavity are two rows of nerve ganglia which are connected with each other and with the brain and spinal cord.

From this double nerve chain extend branches to most of the internal organs and to other ganglia located in the chest and abdomen. The largest of these sympathetic ganglia is the solar plexus, located just below the diaphragm, another is near the heart, and a third low down in the abdomen.

The operation of the sympathetic system is not well understood but it certainly controls the secretion of glands, the regulation of blood supply in arteries, heart action, and probably many other internal activities of which we are not conscious, but without which we could not live.

The "sympathetic system" has nothing to do with "sympathy" in its usual sense, but is so named since it seems to keep the *involuntary* internal organs working in harmony, much as the cerebellum coördinates the action of the voluntary organs.

Processes Centered in the Nervous System.

1. Reception of sense impressions by way of the sense organs and sensory nerves.
2. Mental processes, thought, reason, memory, etc., are associated with brain activity.
3. Voluntary actions originating in the cerebrum and coördinated by the cerebellum.
4. Involuntary and unconscious actions of internal organs, controlled by medulla and sympathetic system.
5. Involuntary but conscious actions (reflex) controlled by the spinal cord.
6. Actions, at first voluntary that have become reflex (automatic), like walking.

Fatigue and Rest. After running fast for half a mile, why do you have to stop? Because you are "tired." Perhaps by running more slowly you can keep it up for a mile. Still there comes a time when you are "tired out" and can go no further.

Now assume that you do stop for an hour, perhaps take a shower bath and brisk rub down. You probably can again run the mile, almost as well as at first. Why? Because you are "rested." You have had no food, no new source of energy,

and yet you can do almost as much work as at first. **What is** the explanation?

Fatigue Toxins. It seems probable that work produces actual poisonous substances in the tissues, which are called "fatigue toxins." These affect the action of muscles, nerves, and glands. Oxidation and excretion remove them as fast as possible. If the rate of work produces fatigue toxins faster than they are removed, some remain in the system and produce fatigue.

If the rate of work is slower, oxidation and excretion come nearer to complete removal, and the fatigue point, where you are "tired out," is postponed. That is one reason why you can run a slow mile easier than a fast half.

During the period of rest, most of the fatigue toxins were removed, the tissues were "rested," and the body became able to work anew. This is the reason for recess periods and relief drills in schools and for "pause periods" which are being introduced among factory workers.

Fatigue toxins affect the secretions of glands and the action of the digestive organs, hence eating while tired often results in indigestion. The white corpuscles are also affected, and though their number is increased, a tired body is actually more liable to infection than one normally rested. Worry, anger, and fear seem to cause toxic effects similar to those of fatigue and should be avoided, both on their own account and because of the physical effects.

Sleep. In the end, a day's work produces an excess of fatigue poisons and the body must have an extended opportunity of getting rid of them. This is provided by sleep. During sleep the body takes care of the accumulated wastes of the day and the working and growing cells have opportunity to repair loss, and increase in number.

This means that sufficient sleep must be had or a condition of chronic fatigue will develop. Young people need more sleep than adults because growth, as well as repair, has to proceed. The amount of sleep required by adults varies widely, but eight hours is a fair average. Children should have more. The

morning should find all fatigue toxins out of the system and the body fully refreshed and ready for another day with yesterday's bills all paid.

Habit Formation. To accomplish a given act or thought, the nerve impulse has to connect up various parts of the brain. At first this is done with difficulty and we say we are "learning to read" or to ride a bicycle or play a piano. However, repeated voluntary acts soon make their proper nerve connections easier, as if a path were being worn in the brain along which the impulses travel with greater and greater ease.

If we continue doing a certain act or thinking a certain way often enough, it becomes the easiest way to act or to think, and we say we have "acquired the habit." If we look up the derivation of that word, *habit*, we find that it comes from "habeo," meaning to have or hold. So instead of our getting the habit, as we say, the habit has "got" us.

It is a serious thing to think of, for our whole life is a complex mass of habits,—things which hold us,—acts and thoughts that do themselves, and which we "just can't help." How careful we should be that those brain paths are the best arranged so that habits of thought shall be prompt and accurate. How watchful we should be that only good and helpful paths be followed, for, whether we wish it or not, the habit will get and hold us. It is only too true that "As a man thinketh . . . so is he."

Habit Selection. Not only are there habits of *doing* which must be acquired, but there are habits of *not doing* (inhibition) which are just as important. We may see an article which we want, but we must learn to refrain from stealing it. We may "feel like" making an angry reply but we can learn to restrain our temper.

Thus we have a choice of habits in two ways. We can acquire habits of *doing* the right thing and also learn to *inhibit* wrong impulses. Habits are not only "right or wrong" in a moral sense. We can choose to form right habits of eating, exercise, posture, or speech and we can elect to refrain from habits that harm our physical bodies.

Habits of *thinking* really precede habits of doing and are of equal or greater importance. Nine times twelve did not always make us think "108," but once the habit was formed it becomes easy and saves much time. Reasoning logically from cause to effect, using control experiments, excluding everything but facts,—this is a kind of thinking that requires effort to make into a habit. Once formed, such a habit is a long step toward a trained mind and efficient intellect.

We can select and train our habits of *feeling* too. We may form the habit of being discouraged by difficulties, or they may only make us the more determined to succeed. We can let ourselves feel snobbish or superior to those less fortunate than we, or we can learn to form habits of charity and tolerance for our neighbor. Whether we will or not, we are forming to-day the habits that will "hold" us throughout life. We must constantly choose between them. We can cultivate useful habits of work and thus become efficient and successful. We can inhibit acts which harm others or ourselves. We can train our minds to be accurate and prompt servants, and we can regulate our feelings so as to have a happy and helpful life. *Or* we can do just the opposite.

The habits which we acquire become so fixed that they control our lives. The sum total of our habits is our *character*. Youth is the time of easiest habit formation. We should choose wisely and practice diligently to acquire only those habits which will build up a strong character.

"The hell to be endured hereafter, of which theology tells, is no worse than the hell we make for ourselves in this world by habitually fashioning our characters in the wrong way. Could the young but realize how soon they will become mere walking bundles of habits, they would give more heed to their conduct while in the plastic state. We are spinning our own fates, good or evil, and never to be undone. Every smallest stroke of virtue or of vice leaves its never-so-little scar. The drunken Rip Van Winkle, in Jefferson's play, excuses himself for every fresh dereliction by saying, 'I won't count this time!' Well! he may not count it, and a kind Heaven may not count it; but

it is being counted none the less. Down among his nerve cells and fibres the molecules are counting it, registering and storing it up to be used against him when the next temptation comes. Nothing we ever do is, in strict scientific literalness, wiped out. Of course this has its good side as well as its bad one. As we become permanent drunkards by so many separate drinks, so we become saints in the moral, and authorities in the practical and scientific, spheres by so many separate acts and hours of work. Let no youth have any anxiety about the upshot of his education, whatever the line of it may be. If he *keep faithfully busy* each hour of the working day, he may safely leave the final result to itself. He can with perfect certainty count on waking up some fine morning, to find himself one of the competent ones of his generation, in whatever pursuit he may have singled out."—James, *Psychology.*

Alcohol and the Nervous System. Alcohol acts directly on the nervous system. In small amounts it produces a feeling of exhilaration, but is soon followed by a reaction and no permanent good is accomplished.

Thorough tests have been made, proving that no mental or physical process is helped by the use of alcohol. Marksmanship, ability to do muscular work, accuracy in mathematics, speed in setting type, all have been used as tests for effects of alcohol. In every case efficiency was decreased, though often the people *thought* they were doing better than without the narcotic. This indicated its effect on the judgment as well as on the actual work done.

To get the same sensations and results, more and more alcohol must be taken and thus a habit is developed which is harmful and difficult to break.

The narcotic effects of alcohol are first evident in their effect on the higher nerve functions of judgment, reason, and morality. This is the cause of many criminal acts and much harm and misery. It is a dangerous drug and of doubtful value even as a medicine. As a beverage its results are always harmful.

COLLATERAL READING

Physiology Textbook, Colton, pp. 254–298; *General Physiology*, Eddy, pp. 382–428; *Applied Physiology*, Overton, pp. 266–275; *Human Mechanism*, Hough and Sedgwick, pp. 266–288; *Human Body and Health*, Davison, pp. 215–236; *Studies in Physiology*, Peabody, pp. 253–290; *Human Body*, Martin, pp. 230–262; *Elementary Physiology*, Huxley, pp. 475–551; *High School Physiology*, Hughes, pp. 214–234; *Elementary Biology*, Gruenberg, pp. 208–223; *Biology of Man and Other Organisms*, Linville, pp. 409–433.

SUMMARY OF CHAPTER XLIV

THE NERVOUS SYSTEM

1. Reason for special training of the brain.

2. Parts of nervous system.

- a. Brain.
  - (1) Cerebrum.
    - (a) Location.
    - (b) Size.
    - (c) Shape.
    - (d) Surface.
    - (e) Character of substance.
    - (f) Functions.
      - 1. Intelligence.
      - 2. Will.
      - 3. Thought.
      - 4. Sensation.
      - 5. Voluntary motion.
  - (2) Cerebellum.
    - (a) Location.
    - (b) Size.
    - (c) Surface.
    - (d) Function.
      - 1. Muscular coördination for voluntary acts.
  - (3) Spinal bulb.
    - (a) Location.
    - (b) Size.
    - (c) Function.
      - 1. Control of respiration, circulation, etc.
- b. Spinal cord.
  - (1) Location.
  - (2) Functions.
    - (a) Nerve connection.
    - (b) Reflex control.
- c. Nerves.
  - (1) Function.
    - (a) Receive sensation.
    - (b) Transmit motion impulses.
  - (2) Neuron structure and action.
  - (3) Reflex action.

- **d.** Sympathetic system.
  - (1) Location.
  - (2) Structure.
    - (a) Plexuses (solar, cardiac, abdominal).
  - (3) Function.
    - (a) Coördinates involuntary actions.

3. Control by nervous system.

- a. Sense impressions.
  - (1) By means of sense organs and cerebrum.
- b. Mental processes.
  - (1) By means of cerebrum.
- c. Voluntary actions.
  - (1) By means of cerebrum and cerebellum.
- d. Involuntary actions (unconscious).
  - (1) By means of spinal bulb and sympathetic system.
- e. Involuntary reflex (conscious).
  - (1) By means of spinal cord.
- f. Automatic actions.
  - (1) By means of the whole system.

4. Fatigue and rest.

5. Habit formation.

6. Habit selection.

7. Alcohol and the nervous system.

CHAPTER XLV

THE SENSE ORGANS

Vocabulary

Irritability, response of simple organs to environment.
Papillæ, minute projections supplied with nerve endings.
Pigment, color substance.
Concentrate, to bring to one point, to focus.

The function of the nervous system chiefly mentioned in the previous chapter was that of *control.* It has another equally important use, namely, to keep us in touch with our surroundings by what we call sensation.

Irritability. All living things respond more or less to their environment. Plants react to light, moisture, contact, and gravitation, and thus have a very simple sort of sensation, usually called "irritability." These responses are sufficient for their needs, as our experiments have shown, and enable plants to reach food and water supplies, to turn leaves toward light, to climb by means of tendrils, and to perform certain movements concerned in pollination and seed dispersal.

Touch. Even the simplest animals are affected by actual contact with surroundings. The amœba recoils from hard or hot particles, absorbs food when in contact with it, and thus may be said to exhibit a primitive sense of touch.

In higher forms, the whole body surface possesses this sense more or less. It is often especially developed in tentacles, hairs, or papillæ in various animals. In man the sense of touch is common to all parts of the skin, especially the finger tips, forehead, and tongue. The human skin also possesses special nerves that receive temperature, pressure, and pain impressions. If we gently touch different places on the back of the hand with a pencil point, some spots will feel warm and others cold, due to the presence or absence of these temperature nerves.

Taste. All animals seem to prefer some foods and reject others. We have to assume a sort of taste sense to account for this. To be tasted, a substance has to be in solution and in contact with certain organs near the mouth. The mouth parts, palpi, and tongue are the usual taste organs, and in man the different parts of the tongue are sensitive to different tastes. The back part responds only to bitter, the tip to sweet, the sides to sour, and the whole surface to salty flavors. Much that we attribute to taste is really due to the sense of smell; if eyes and nose are closed one can hardly distinguish between an apple, onion, or raw potato. Taste enables animals to judge of foods, stimulates the flow of digestive fluids, and in aquatic forms may give information as to their location in the water.

Smell. Both touch and taste require the substance to be in actual contact if it is perceived. Smell reaches a little farther away and enables animals to detect substances in the form of vapor or dilute solution, even though at a distance.

The organs of smell are sometimes hairs, often antennæ, while vertebrates have some sort of a "nose." They are usually near the food-getting organs, and in air breathers, are associated with the inlet to the lungs. Primarily the sense of smell is used to judge of food and air supply but in many cases it is also useful in finding food, detecting enemies, and locating mates. It is little developed in aquatic animals but very keen in insects, carnivora, and most ungulates.

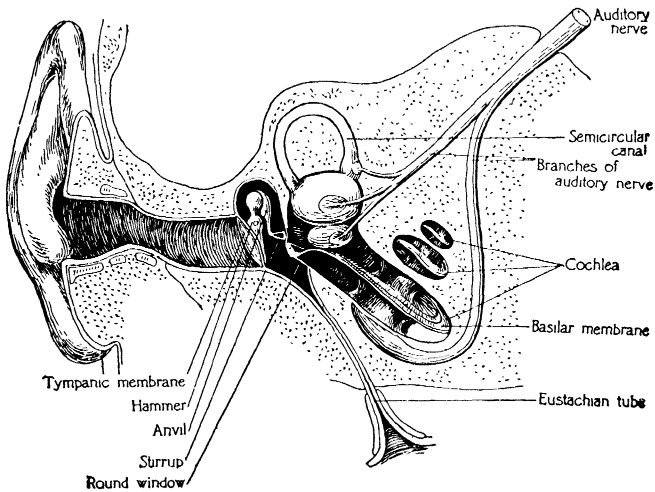
Hearing. In contrast to the three senses mentioned above, hearing puts us in touch with our surroundings through the medium of sound waves conveyed by air or water. This brings within range of our consciousness things at a much greater distance and is the chief avenue of communication among all higher animals, most of which possess some form of sound-producing organs.

The simplest ears in the lower animals consist of mere sacs lined with nerve endings and may be balancing organs rather than true ears. In insects the sacs are covered with a tympanum or drum membrane, and possibly the antennæ are sensitive to

sound vibrations as well. Ear organs may be located on legs, abdomen, antennæ, and head in various animals.

Structure of the Human Ear. The vertebrate ear is a wonderfully complicated organ. The external ear opens into an auditory canal embedded in the skull. This canal is closed at its inner end by the *tympanic membrane* which separates it from the middle ear.

The middle ear connects with the throat by way of the Eustachian tube which serves to equalize the air pressure on both sides



From Kellogg.

FIG. 168. Semi-diagrammatic section through the right ear.

of the drum and thus prevents breakage, while permitting free vibration. Across the middle ear extends a chain of tiny bones which connects the tympanic membrane with a somewhat similar membrane in the wall of the inner ear.

The internal ear consists of two general parts. The *cochlea* is a cavity in the skull shaped like a snail shell. It is filled with a liquid and lined with a complicated set of nerve endings, which receive the sound impressions. The *semicircular canals,* three in number, are little loop-shaped tubes each at right angles to the other, and have to do with maintaining the balance of the body.

How We Hear. When a person speaks to us, he starts certain air waves which are gathered in by the external ear, and conveyed to the tympanum, which is thus made to vibrate. By means of the bones of the middle ear, this vibration is communicated to the fluid in the inner ear, and this in turn acts upon the nerve endings of the cochlea. This disturbance of the nerve endings is transmitted to the brain by way of the auditory nerves and we hear the sound of words.

The human ear can distinguish vibrations varying from sixteen to forty thousand per second, but we have reason to believe that insects can hear sounds of higher pitch.

Care of the Ears. Fortunately this delicate and important organ is deeply embedded in the skull where little harm can reach it, but care must be observed not to injure the tympanum by probing with hard implements, ear spoons, etc., when trying to clean the ear. In this connection it has been said that one ought never to explore their ears with anything sharper than their elbow.

Ear wax has a useful function in keeping out dirt and insects, and excess can be properly removed by ordinary washing. Foreign bodies should be washed out and never removed by "poking" with hairpins and other implements. Water which enters the ears in diving does no harm, and can easily be shaken out.

Ear ache or a discharge from the ear may indicate a serious condition and should have immediate attention from a physician. The brain and ear cavities are very close together at one point, so that inflammation of the ear may reach the brain with fatal results.

Temporary deafness may be caused by inflammation of the Eustachian tubes as a result of a cold. Permanent deafness may be caused by a blow on the ear bursting the tympanum, or by disease of the middle or inner ear. It is always a serious matter and should never be treated by advertising quack doctors, whose only skill consists in their ability to separate their victims from their money.

Sight. Plants and the simplest animals respond to light but can hardly be said to "see." The sensation of sight reaches us

by way of waves in the ether, which are studied more fully in Physics. These light waves reach us from vast distances and at enormous speed and put us in touch with a wider extent of our surroundings than all the other senses combined. This fact, with its relation to our other activities, makes sight the most valued of all our senses. Yet there is hardly an organ that we abuse more than we do our eyes.

The simplest eyes were mere colored spots connected with special nerves to absorb light and tell its direction. Now we have lenses developed to concentrate light upon these sensitive pigment spots, muscles to adjust both lens and eye and various devices to protect the whole.

Structure of the Human Eye. The eye is almost spherical in shape, flattened a little from front to rear. The wall of the eye-ball consists of three layers. The outer one is tough and white, called the *sclerotic* coat, and shows in front as the "white of the eye." The anterior surface of the sclerotic bulges out a little, and becomes transparent in the circular region called the *cornea.*

The second coat, called the *choroid,* is richly supplied with blood vessels and pigment (color) cells which prevent reflection of light inside the eye-ball. This coat shows in front as the *iris* or "color" of the eye. The iris is provided with muscles which regulate the size of the centre opening, the pupil, according to the amount of light.

The inner layer is the most delicate and complicated part of the eye and is called the *retina.* It is really the expanded end of the optic nerve and connects directly with the brain. It also has a dark pigment and though only $\frac{1}{80}$ of an inch in thickness, it consists of at least seven distinct layers of cells which help in receiving the impression which we call sight.

The lens of the eye is located just behind the iris and is connected to the choroid by delicate muscles which can change its thickness, to adjust for near or distant vision.

The space in front between the lens and cornea is filled with a watery fluid and the ball of the eye is occupied by a jelly-like, transparent substance, which keeps the eye in shape.

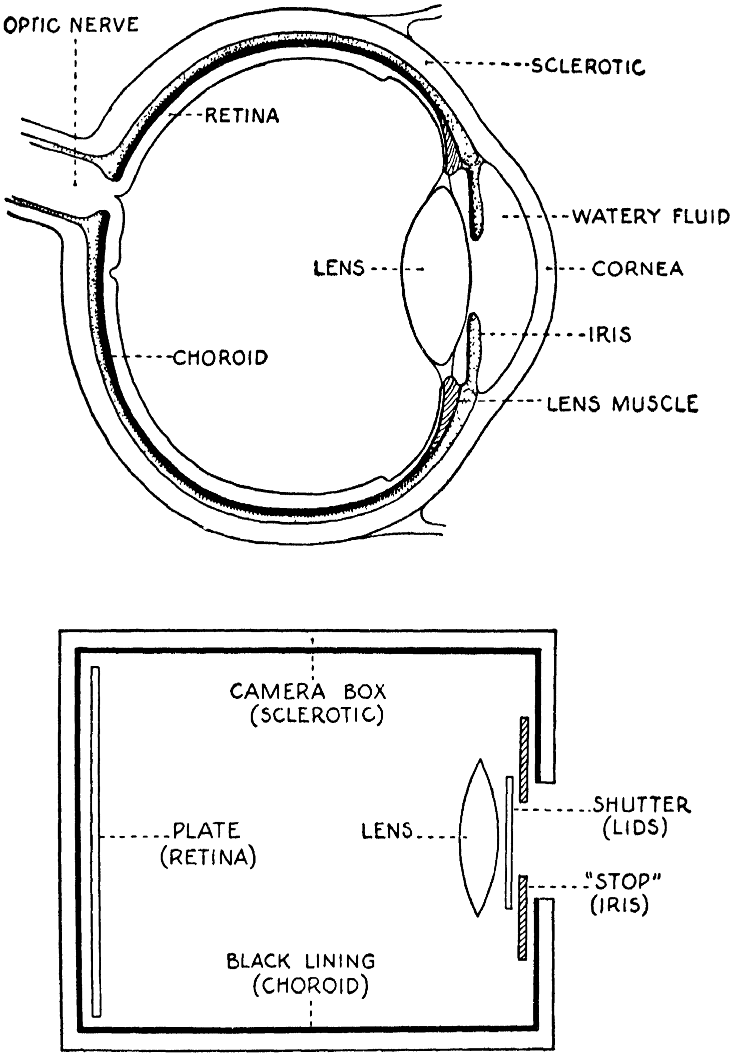


FIG. 169. Diagram to show comparison between the eye and the camera.

How We See. Light waves from an object pass through the cornea to the lens which concentrates (focuses) them upon the retina as you would focus a picture on the film of your camera. The iris controls the amount of light entering the eye and the lens muscles change its shape so that the picture on the retina may be sharp and clear. The retina is affected by the light that falls upon it and the impression is carried to the brain by the optic nerve, as sight.

Protection of the Eye. Obviously, the eye cannot be buried in the skull for protection, like the ear, but it is well guarded none the less. The bony socket, walled in by the forehead, nose, and cheek ward off any but direct blows. The pad of fat on which it rests saves it from jar or pressure. The eyebrows keep out perspiration and the lids and lashes protect from dust. Tear secretion constantly washes the front surface and a complicated set of reflex actions helps us to ward off most injuries to this important sense organ.

The Living Camera. The eye is often compared to a camera and there are so many resemblances, that it may be helpful to study this table of comparisons.

Part of eye	corresponding to	Part of camera
Ball		Camera box
Lens		Lens
Lids		Shutter
Iris		Stops or diaphragm
Pupil		Lens opening
Lens muscles		Focusing devices
Black pigment		Black lining
Retina		Plate or film

In making this comparison it must always be borne in mind that there are also fundamental differences. The eye is alive, the camera is not. The eye produces a sensation within the brain, the camera makes a picture. The eye focuses by changing the *shape* of the lens, the camera, by changing its distance from the film.

Defects of the Eye. The care of the eye is dealt with in the chapter on hygiene, but it is well to remember that seldom are

Comparison of Sensations

Sense	Organs	Medium	Uses	Examples	Range
Touch	Surface Skin, hairs Tentacles Papillæ	Contact with solids	Recognition of food and surroundings	Most widely distributed Simplest	Actual contact
Taste	Palpi Mouth parts Tongue	Contact with substances in solution	To judge food and surroundings	Less general	Solution in contact
Smell	Antennæ Hairs Nose	Vapor particles	To judge of food and air, locate enemies and mates	Keen in the carnivora, ungulates and insects	Semi distant contact
Hearing	Sac and nerve endings. Ears, antennæ, hairs, tympanum	Air waves	Communication Warning Implies sound making organs	Sacs in polyp, worm, mollusc, and crustacea Tympanum in insects and vertebrates	Distant Voice *vs.* speech
Sight	Pigment spots Retina, lens, nerves	Ether waves	Most valuable in all above uses	Compound and simple eyes	Vast distance

they perfectly normal and frequent examination by a competent physician is the only sure way of preserving their health. Below are tabulated some of the common conditions and their causes, but only an expert can determine the exact kind of lens or method of treatment which will remedy the defect.

Condition	Defect of eye	Remedy
Near sight	Eye-ball too long or lens too curved	Concave lens glasses
Far sight	Eye-ball too short or lens too flat	Convex lens glasses
Astigmatism	Irregularity in shape of lens, or cornea	Special cylinder lens glasses
Old age	Loss of lens adjustment resulting in far sight	Convex lens glasses

COLLATERAL READING

Animal Studies, Jordan, Kellogg and Heath, pp. 371–386; *Animal Life*, Jordan and Kellogg, pp. 224–239; *Physiology Textbook*, Colton, pp. 284–300; *General Physiology*, Eddy, pp. 436–485; *Applied Physiology*, Overton, pp. 268–275; *The Human Mechanism*, Hough and Sedgwick, pp. 244–265; *The Human Body and Health*, Davison, pp. 237–258; *Studies in Physiology*, Peabody, pp. 291–320; *The Human Body*, Martin, pp. 263–294; *Elementary Physiology*, Huxley, pp. 367–457; *High School Physiology*, Hughes, pp. 239–260.

SUMMARY OF CHAPTER XLV

THE SENSE ORGANS

1. Irritability.

2. Touch.

3. Taste.

4. Smell.

5. Hearing.
- a. Structure of ear.
  - (1) Outer ear.
    - (a) Lobe.
    - (b) Auditory canal.
  - (2) Middle ear.
    - (a) Bones.
    - (b) Eustachian tube.

(3) Inner ear.
(a) Cochlea.
(b) Nerve endings.
(c) Semicircular canals.
b. How we hear.
c. Care of ears.

6. Sight.
a. Structure of eye.
(1) Coats.
(a) Sclerotic.
1. White.
2. Thick.
3. Protective.
4. Cornea in front.
(b) Choroid.
1. Blood vessels.
2. Pigment.
3. Iris in front.
(c) Retina.
1. Dark.
2. Complicated.
3. Receives impressions.
(2) Lens.
(a) Convex.
(b) Adjustable by muscles.
b. How we see.
c. Protection of the eye.
d. The living camera.
e. Defects of the eye.

CHAPTER XLVI

BIOLOGY AND HEALTH

Vocabulary

Excessive, more than necessary.
Mastication, chewing.
Flexible, easily bent.
Vagaries, whims.

One of the chief reasons for the study of biology is to learn how to properly care for our own body and to maintain both it and its surroundings in healthful condition.

The science which deals with the care and health of the body is called *hygiene;* that which deals with keeping its environment healthful is called *sanitation.*

A great many foolish "rules of hygiene" have been devised but if we will apply our general knowledge of biology, mixed with a goodly amount of common sense (which is not common), we can construct our own. We know the amount and kinds of foods required, and can judge the evils of improper or excessive eating. We know the need and process of digestion and can reach our own conclusion as to chewing food, care of teeth, removal of waste, etc.

We have learned the use of oxidation and can see the reason for correct posture, clothing, and exercise, which affect breathing. In this way a sensible human being ought to be able to apply biology to his own life and it is much better than trying to memorize any set of rules, however wise they may be.

In the same way, sanitation means the knowledge of biology as applied to food and water supply, infectious diseases, ventilation, sewerage, clean streets, etc.

In our elementary work we have studied both these subjects to some extent. This chapter will merely attempt to summarize a few of the principal facts. It also includes valuable sugges-

tions on some of the topics, taken from the Yale Lectures on Hygiene, by Professor Irving Fisher.

Health is the *natural condition* of the body, and yet, how many have never been sick, or are now in absolutely perfect health. We must remember that any lack of health is due to some biologic mistake. While we can probably never know enough to absolutely avoid disease certainly our study of biology ought to help us to escape those troubles whose causes we *do* know. If we lived as well as we knew how, everybody would be much stronger, healthier, and happier. It is to call attention to some of the simpler applications of biology to health, that this chapter is written.

Hygiene of the Muscles. A great deal is being done with regard to proper muscular exercise and it is well to understand some of the reasons for the importance of this matter. The least important result is one most often mentioned, namely, the fact that exercises *strengthen* the muscles used. This is true but the following results are much more important to health:

1. Exercise increases oxidation, from three to ten times; this means that greater bodily energy is liberated.

2. From this it follows that the heat-regulating and excretory organs are trained to their work.

3. Exercise withdraws the blood from the internal organs to the muscles and so relieves the tendency to over-supply and congestion; this is shown by the "healthy color" of the complexion due to the blood supply in the outer muscles; a very pale skin usually indicates poor health.

4. Only by proper exercise do the heart and arteries receive necessary training in supplying the blood to the tissues.

5. In the same way, exercise aids in the use and health of the lungs and breathing organs.

6. Motion of the muscles is one of the chief causes of lymph flow and we know that upon the lymph circulation depends the nutrition of the tissues.

No rules can be given as to special kinds of exercise, since different people need different forms, just as we need different amounts of food, but in general it may be said that any exercise

should bring about the results mentioned above, and should not be such as to endanger or overstrain any part of the body.

Proper exercise should

1. Be vigorous, continuous, and reasonably prolonged. For example a brisk walk is one of the best of exercises, while a short stroll or saunter does little good, though often mistaken for "exercise."

2. Useful exercise should use the *body muscles* as well as arms and legs: walking, swimming, and throwing are good examples.

3. Exercise should cause full, deep breathing and preferably should be in the open air. Loose clothing and erect position necessarily follow.

4. Exercise should be *varied* and should occupy the *mind* as well as the body; any movements, however excellent, lose much if they are not enjoyed while being performed. This is the objection to many really beneficial "systems of exercise" which become very distasteful because of lack of interest.

Exercise and Rest. The hygienic life should have a proper balance between rest and exercise of various kinds, physical and mental. Generally every muscle in the body should be exercised daily.

Muscular exercise should hold the attention, and call into play will power. Exercise should be enjoyed as play, not endured as work.

The most beneficial exercises are those which stimulate the action of the heart and lungs, such as rapid walking, running, hill climbing, and swimming.

The exercise of the abdominal muscles is the most important in order to give tone to those muscles and thus aid the portal circulation. For the same reason erect posture, not only in standing, but in sitting, is important. Support the hollow of the back by a cushion or otherwise.

Exercise should always be limited by fatigue, which brings with it fatigue poisons. This is nature's signal when to rest. If one's use of diet and air is proper, the fatigue point will be much further off than otherwise.

One should learn to relax when not in activity. The habit

produces rest, even between exertions very close together, and enables one to continue to repeat those exertions for a much longer time than otherwise. The habit of lying down when tired is a good one.

The same principles apply to mental rest. Avoid worry, anger, fear, excitement, hate, jealousy, grief, and all depressing or abnormal mental states. This is to be done not so much by repressing these feelings as by *dropping* or ignoring them—that is, by diverting and controlling the attention. The secret of mental hygiene lies in the direction of attention. One's mental attitude, from a hygienic standpoint, ought to be optimistic and serene, and this attitude should be striven for not only in order to produce health, but as an end in itself, for which, in fact, even health is properly sought. In addition, the individual should, of course, avoid infection, poisons, and other dangers.

Occasional physical examination by a *competent* medical examiner is advisable. In case of illness, competent medical treatment should be sought.

Finally, the duty of the individual does not end with personal hygiene. He should take part in the movements to secure better public hygiene in city, state, and nation. He has a selfish as well as an altruistic motive to do this. His air, water, and food depend on health legislation and administration.

Food. Teeth should be brushed *thoroughly* several times a day, and floss silk used between the teeth. Persistence in keeping the mouth clean is not only good for the teeth, but for the stomach.

Masticate all food up to the point of involuntary swallowing, with the attention on the taste, not on the mastication. Food should simply be chewed and relished, with no thought of swallowing. There should be no more effort to prevent than to force swallowing. It will be found that if you attend only to the agreeable task of extracting the flavors of your food, Nature will take care of the swallowing, and this will become, like breathing, involuntary. The more you rely on instinct, the more normal, stronger, and surer the instinct becomes.

The instinct by which most people eat is perverted through the "hurry habit" and the use of abnormal foods. Thorough mastication takes time, and therefore one must not feel hurried at meals if the best results are to be secured.

Sip liquids, except water, and mix with saliva as though they were solids.

The stopping point for eating should be at the *earliest* moment when one is really satisfied.

The frequency of meals and time to take them should be so adjusted that no meal is taken before a previous meal is well out of the way, in order that the stomach may have had time to rest and prepare new juices. Normal appetite is a good guide in this respect. One's best sleep is on an empty stomach. Food puts one to sleep by diverting blood from the head, but disturbs sleep later. Water, however, or even fruit may be taken before retiring without injury.

An exclusive diet is usually unsafe. Even foods which are not ideally the best are probably needed when no better are available, or when the appetite especially calls for them.

The amount of protein required is much less than ordinarily consumed.

The sudden or artificial reduction in protein to the ideal standard is apt to produce temporarily a "sour stomach," unless fats be used abundantly.

To balance each meal is of the utmost importance. When one can trust the appetite, it is an almost infallible method of balancing, but some knowledge of foods will help. The aim, however, should always be—and this cannot be too often repeated—to educate the appetite to the point of deciding all these questions automatically.

Be sure that the water you drink is free from dangerous germs and impurities. "Soft" water is better than "hard" water. Ice water should be avoided unless sipped and warmed in the mouth. Ice may contain *spores* of germs even when germs themselves are killed by cold.

Cool water drinking, including especially a glass half an hour before breakfast and on retiring, is a remedy for constipation.

Hygiene of Digestion. For the general study of foods refer to Chapter XXXIX. The following is a summary of facts explained there:

1. The amount and kind of food should be adjusted to the work of the body. Vitamins should be supplied.
2. The "balance" of the ration should be maintained.
3. The food should be clean and properly prepared.
4. Usually the heartiest meal should come after the day's work and should be preceded by a brief rest. Only when the brain or muscles are not working, can the digestive organs get proper supply of blood.
5. Eating between meals is usually a bad practice, especially in case of sweet foods, as it prevents proper desire for, and digestion of, the solid food which the body requires.
6. Water in abundance should be used both between and at meals, but not to "wash down" unchewed food. It does not "dilute the gastric fluid" but passes quickly from the stomach and digestion is aided rather than hindered.
7. It is unnecessary to dwell upon the importance of thorough chewing. The smaller the food particles, the greater the surface exposed for digestion and the less burden is put upon the stomach. The starch digestion in the mouth may not be very extensive, but thorough mastication prevents over-eating and too rapid eating, both of which produce more indigestion than all other causes put together. "Leave the table hungry" is a good rule. Americans eat too much, particularly of protein foods, a habit which is both unhealthful and expensive.
8. Proper care of the teeth is necessary if food is to be thoroughly chewed. It is sufficient to remember that tooth decay is a bacterial process, that the warmth and moisture of the mouth make ideal conditions for bacterial growth, and that perfect cleanliness is our only means of protection. This suggests frequent careful brushing, and a visit to a dentist at least twice a year "whether you need it or not."
9. Violent exercise, severe study, worry, or any mental or physical activity, at or near meal-times interferes with proper digestion.

10. Regular attention must be given to the removal of waste from the intestine, as a long series of illnesses can be traced to lack of care in this regard.

Hygiene of the Teeth. The importance of dental hygiene has been mentioned before but cannot be too much emphasized. Conditions in the mouth are ideal for the growth of bacteria which cause decay. Warmth and moisture are sure to be present, and unless great care is observed, particles of food will remain for the bacteria to feed upon.

It is not a pleasant experiment, but if the teeth be scraped with the finger nail and the odor of the substance removed observed, we will have no doubt that decay is going on. The total area of possible tooth infection is equal to that of two standard petri dishes (over twelve square inches).

The decay of food between the teeth destroys the protective enamel and the dentine then goes rapidly. The immediate results are bad breath, pain, and loss of teeth. Fully as serious are the secondary consequences of poor chewing: indigestion, pus diseases from infected gums, rheumatism, and nervous disorders. Tonsils, throat, ears, and even the lungs may be infected from the teeth.

The first or "milk teeth" deserve as great care as the permanent set. If they decay and are removed too soon the jaws and face never attain their proper shape and proportion, and the later teeth will not fit properly together.

Hygiene of Respiration. We have learned the use which the body makes of oxygen in releasing the energy in our foods and keeping us alive and active. Naturally, proper breathing is required if this process is to go on in a healthful way.

We need to train our breathing muscles, because few of us know how to breathe, even though we use the expression "natural as breathing." Correct breathing means using more lung tissue, getting more oxygen, and developing the diaphragm and rib muscles properly. We cannot use *all* our lung capacity at once, but should use all we can. We train the other muscles for less important uses; why not train our breathing muscles for the race of life? Erect position and comfortable clothing are

necessary if we are to breathe properly. The nose was made for breathing, not the mouth (see Chap. XLI).

Tonsils and adenoids should be examined by a competent physician, and removed if diseased or enlarged enough to interfere with breathing.

Air. Keep outdoors as much as possible.

Breathe through the nose, not through the mouth.

When indoors, have the air as fresh as possible—

(*a*) By having aired the room before occupancy.

(*b*) By having it continuously ventilated while occupied.

Not only purity, but coolness, dryness, and motion of the air if not very extreme, are advantageous. Air in heated houses in winter is usually too dry, and may be moistened with advantage.

Clothing should be sufficient to keep one warm. The minimum that will secure this result is the best. The more porous your clothes, the more the skin is educated to perform its functions with increasingly less need for protection. Take an air bath as often and as long as possible.

Ventilation. Deep breathing will do little good if the air breathed is bad: this means attention to ventilation. Proper ventilation should secure:

1. A sufficient amount of air in proportion to the number concerned.

2. A slight continuous movement of air through the whole room, without perceptible drafts.

3. A moderate degree of heat, usually 68 degrees or less.

4. The removal of excess moisture which is especially great in crowded rooms.

5. The removal of chemical impurities and odors.

"Fresh air" is not necessarily cold air as some people seem to think, though for sleeping rooms the temperature should be lower than in living quarters. Extreme cold is not an advantage even in sleeping rooms, except in cases of tuberculosis, and many people subject themselves to dangerous exposure in this way. Air should be pure, cool, and abundant, but there is no virtue in extreme coldness.

Dust Removal. Dust carries bacteria, hence air should be as free from it as possible. This means replacing the broom and feather duster by the vacuum cleaner and oiled dust cloth. Rugs and hard-wood floors should take the place of the permanent carpet. Smooth walls, simple furniture, and few hangings offer less opportunity for the accumulation of dust. Sprinkling, oiling, and flushing the streets attain the same result for out-door dust.

Hygiene of the Eyes. The human eye is such a delicate and necessary structure that its care should be emphasized, but just because it is so complicated, no rules can be made which will properly safeguard this most valuable sense organ. The one safe procedure is to have the eyes examined by a competent expert from time to time, even if no defect appears to be developing.

Reading in poor light, or at evening when the light is gradually failing, is a common error. Almost as bad is the use of too bright light directly facing the eyes, or reflected from too shiny paper in books. Long continued use of the eyes on very fine print or sewing causes severe strain, just as in continued use of any other organ.

Actual defects in structure or, more often, over use under poor conditions, produce "eye strain" and from this result headache, sleeplessness, and nervous troubles of serious nature, in addition to the damage to the eye itself. Common sense in their use, immediate rest when any feeling of fatigue is caused, and prompt advice from an expert, are the only rules for the care of our eyes.

Hygiene of Bathing. Washing is primarily to remove dirt. Dirt is objectionable for two reasons: it is offensive to refined people and it often carries disease germs.

Washing to "keep the pores open" is not a true reason, because the skin excretes but little waste, and the pores open quickly, even in the dirtiest skin, when perspiration is required for heat regulation.

There is a strong argument for a daily *cold* bath, because it gives the skin practice in adjusting itself to sudden changes of temperature similar to those it encounters in every day exposure.

The cold shower or sponge bath, if followed by brisk rubbing, causes the skin arteries to contract, and then expand again, as evidenced by the glow of the skin.

This is precisely what the body should do when exposed to sudden chill of any sort, and if trained by frequent cold bathing, the arteries will be ready to regulate the blood supply and no cold or congestion will result.

Neither cold bathing nor swimming should be done within at least an hour after meals, as the blood is needed to absorb the food, and should not be diverted to the skin. The bath should not be so cold, nor the swim so long continued, as to cause a permanent chill or prevent the warm reaction when the body is rubbed dry.

The cold bath is primarily a means of prevention of "colds" and all that they lead to; it should be taken daily in the morning, immediately upon rising. The warm bath is solely a means of cleansing the skin, should not be taken every day and only just before retiring, when precautions to prevent chill can be observed. A very hot bath should be taken only by physician's orders.

Hygiene of the Feet. With the possible exception of the eye, no human organ has been worse abused than the foot. We crowd our feet into air-tight leather boxes, bend the toes together, lift the heel high off the ground and then wonder why we suffer from corns, bunions, and fallen arches. Proper shoes should have their inner edges nearly straight, heel low and broad, toe with room enough so that the toes can separate and "wiggle." The uppers should be flexible, as porous as possible, and not too tightly laced. The arch of a normal bare foot should not touch the floor on the inner edge and the shoe should be so shaped as to support this upward curve. The selection of shoes should be guided by the expert advice of a doctor or trained fitter and not be governed by the vagaries of style or the demands of fashion. Feet were made to walk on, not to look at. In walking the feet should be carried forward with the toes straight ahead, not turned out as is commonly done. "Toeing out" is as abnormal as "toeing in" but is so common that it is less noticed.

Flat feet and fallen arches are frequently caused by improper shoes or by wearing shoes badly "run over." This condition is often painful, sometimes leads to other disorders, and may interfere seriously with standing or walking.

An exercise suggested for one type of fallen arch consists in standing "toed in" and rising on the toes several times every day. This will strengthen one of the foot arches but might not help if the trouble was in a different part of the foot. Standing on the outer edge of the foot and curling the toes back toward the heel is another helpful exercise. Walking with feet parallel and toes straight ahead is the correct way to walk and tends to prevent flat feet.

Treatment of foot disorders is not a simple matter and an expert should be consulted whenever necessary.

Posture. *Standing.* The human animal is not as yet completely adapted to his erect position. This makes especial care necessary to achieve a healthful posture both in walking and sitting.

The head should be held up in a natural position with chin drawn back, not stiffly, but with the feeling that you are pushing your hat up. The shoulders may be either sloping or square by nature, but need never be rounded forward. If we still walked on all fours they would be pushed back by our weight; now we reverse the process and carry weight upon them. This makes it especially needful that we hold our shoulders back and our chest up to give proper play to the lungs.

The abdominal organs tend to press each other down and forward. This has to be met, partly by raising the chest and partly by strengthening the front body walls, to hold them in place.

Sitting. In our modern life we do so much work sitting down, especially reading and writing, that particular care has to be exercised in regard to this. The shoulders are apt to be bent forward, the spine twisted sidewise, and the weight brought too high up by sliding down in the chair. All these habits cramp the breathing and digestive organs and may produce permanent deformity or bad health. The obvious remedy is to sit back in the chair, with shoulders up, and lean forward only from the hips.

Hygiene of the Nerves. Man has reached the stage where mental activity takes the place of physical exertion and there is consequent danger of one-sided development.

Mental fatigue is just as real as muscular fatigue. The brain should not be forced to work when it is already tired nor when the energy of the body has been used in hard physical labor.

Mental hygiene is just as important as physical hygiene. A well-trained brain, developed by proper exercise, is vastly more valuable than powerful muscles and needs even greater care in its development. True education means just this training and developing of a skillful brain, rather than merely storing the mind with various kinds of information. Accumulation of facts is a very important function of the brain, it is true, but is not to be compared with developing it to observe, think, and really reason.

Sleep is the period of rest from nerve activity, relaxation of muscles, repair of waste, and growth of new tissue. Because children are growing as well as using tissue by their intense activity, they need more sleep than the adult. While seven to nine hours' sleep will do for most grown-ups, children ought to have from ten to twelve hours.

COLLATERAL READING

School Hygiene, Shaw, entire; *Outlines of Practical Sanitation*, Bashore, see index; *The Health of the City*, Godfrey, see index; *Handbook of Health*, Hutchinson, entire; *Preventable Diseases*, Hutchinson, entire; *Civics and Health*, Allen, see index; *Primer of Sanitation*, Ritchie, entire; *Good Health*, Jewett, entire; *Mind and Work*, Gulick, entire; *The Human Body and Health*, Davison, see index; *The Human Mechanism*, Hough and Sedgwick, pp. 289–540; *General Hygiene*, Overton, see index; *Applied Biology*, Bigelow, pp. 525–560; Publications of Rockefeller Institute for Medical Research—N. Y. City.

SUMMARY OF CHAPTER XLVI

BIOLOGY AND HEALTH

1. Hygiene of muscles.
- a. Exercise.
  - (1) Reasons for exercise.
    - (a) Increases oxidation.
    - (b) Trains heat regulating and excretion.

(c) Prevents internal congestion.
(d) Trains heart and arteries.
(e) Trains breathing organs.
(f) Aids lymph circulation.
(2) Requirements of proper exercise.
(a) Should be vigorous.
(b) Should use body muscles.
(c) Should cause deep breathing.
(d) Should occupy mind.
(3) Exercise and rest.

2. Hygiene of digestion.

a. Food.
(1) Should be adapted to body needs.
(2) Balanced ration.
(3) Should be clean and well prepared.
(4) Should be eaten when rested.
(5) Should be eaten at regular times.
(6) Should be accompanied by water.
(7) Should be thoroughly chewed.

b. Errors affecting digestion.
(1) Rapid eating.
(2) Insufficient chewing.
(3) Washing down food.
(4) Eating too much.
(5) Not getting rid of waste.

c. Care of teeth.
(1) Frequent cleaning.
(2) Care of first set.
(3) Consult dentist often.

3. Hygiene of respiration.

a. Train your breathing muscles, ribs, and diaphragm.
b. Loose clothing for free action.
c. Erect position to allow lung action.
d. Ventilation, not necessarily cold.
(1) Essentials for proper ventilation.
(2) Dust removal.

4. Care of the eyes.

a. Have frequent examinations.
b. Provide proper light, not too bright.
c. Avoid shiny papers.
d. Avoid continued severe use, producing fatigue.
e. Avoid reading in failing evening light.
f. Serious troubles follow abuse of eyes.

5. Hygiene of bathing.

a. Hot baths.
(1) For decency and cleanliness.

(2) Not to "open the pores."
(3) Not too frequently.
(4) Best at bed time (to avoid chilling).

b. Cold baths.
(1) To train body against chilling.
(2) Should be followed by rubbing and "glow."
(3) Best taken in morning.
(4) Not too cold, nor too prolonged.

6. Hygiene of the feet.

a. Danger from improper shoes.
b. Shape and material of shoes.
c. Correct habits of walking.
d. Support of the arches of the feet.

7. Correct posture.

a. Standing position.
b. Sitting position.

8. Hygiene of the nervous system.

a. Great development of the nervous system.
b. Possibility of overstrain and neglect of rest of body.
c. Importance of well-trained brain.
d. Importance of sleep.

9. Sanitation.

a. Provides healthful surroundings.
b. Deals with water supply, drainage, ventilation, etc.

10. Hygiene.

a. Provides for care and health of body.
b. Deals with exercise, food, care of body, etc.

CHAPTER XLVII

CIVIC BIOLOGY

Vocabulary

Civic, pertaining to government.
Prolific, abundant.
Conservation, saving from waste or damage.
Addiction, the grip of habit.

The preceding chapter has dealt mainly with biology as related to the individual, but equally important is our duty to the health of the community, state, and nation.

Out of two and one-half million babies born in the United States every year, one-half die before reaching the age of twenty-three years, and 500,000 die before their first birthday. Of the adults, 40,000 will have been invalids, 5000 will be in various institutions for mentally or physically unfit, and 100,000 will be inferior to the extent of reducing their value as citizens.

School examinations in Brooklyn show that 72 per cent of the pupils need some form of medical treatment. If this ratio holds for the United States it would mean 14,000,000 children who are in need of health improvement. These figures are not given to cause any feeling of discouragement, but rather to show what great need there is for civic control in all matters pertaining to health, and for the intelligent coöperation of every citizen in these measures.

Already modern methods of hygiene and sanitation have added fifteen years to the human life. In the Spanish war we lost fourteen men by disease for every one that died of wounds. In the Russo-Japanese war, with modern sanitary precautions in force, the Japanese lost only one by disease for every four killed, a record fifty-six times as good as ours.

During the World War, modern principles of sanitation, vaccination, serum treatment, surgery, and the relation of insects to disease, were thoroughly applied.

Vaccination against typhoid was compulsory, the anti-tetanus serum was universally used, new methods of treatment for infected wounds, devised by Dr. Carrel and others were in constant use. Every soldier was provided with iodine to sterilize a wound and aseptic bandages to make a temporary dressing.

As a result of these various applications of biologic science to army methods, the loss from infectious disease was very low. "If the Civil War death rate had obtained in the recent war, we would have lost 138,518 American soldiers from typhoid, dysentery, malaria, and small-pox instead of 273, which was the actual number," says Dr. Henry Smith Williams in one report (Dec. 1919).

We are waging a winning fight against disease and this chapter will touch briefly upon some of the methods by which it is being carried on. We are all soldiers in the army of Public Health and cannot be too well informed as to what must be done to gain complete victory.

Food Control. Almost every town and city has regulations as regards food inspection. The stores, bakeries, slaughter houses and milk stations are under supervision of official inspectors. Foods must be protected from flies, bread must be wrapped, food animals examined as to their health, and fair weight and measure must be given the purchaser.

Water supplies are provided at enormous expense, the water shed is carefully guarded from pollution, the water itself is filtered and chemically treated to remove bacteria. Chemists and bacteriologists are constantly employed to attend to these matters.

Milk has always been a prolific source of disease among young children and every means is now taken to secure its purity and freshness. The farmer must have healthy cows and healthy men to care for them, he must have clean stables and sterilized cans and utensils. The inspectors of State or city enforce a list of rules covering in some cases over sixty items that tend toward supplying clean milk to the dealer in the city.

The dealer is again subject to equally careful control. He must not let the milk get warmer than fifty degrees, he must

provide clean cans and handling conditions, he must sell in sealed and labeled bottles, and his milk must be subject to examination for bacteria, at any time. If any of these conditions are found dangerous, the milk is destroyed.

Milk normally contains bacteria, mostly harmless and some useful, but the total must not exceed 100,000 per cubic centimeter which is not very numerous for bacteria, though well-handled milk ought to be kept far below this limit. Milk must have at least 3.25 per cent of butter fat and must not contain any preservatives, such as borax, soda, or formaldehyde.

The Federal "Pure Food and Drug" law was enacted in 1906 and regulates

1. Inspection of all food animals.
2. Standards of purity for food products.
3. Freedom from adulteration.
4. Prevention of harmful preservatives.
5. Proper labeling of drugs and medicines.
6. Proper labeling of package goods.

Sanitation. Regulations as to sewage and garbage disposal are in force in most cities, and means are provided at public expense for the sanitary disposal of all wastes. Stables and out-houses are either forbidden or restricted. Factories are not permitted to pollute the air or water with their waste products.

Streets are drained, sprinkled, oiled, paved, and flushed with water to remove dirt and to prevent dust. Trees and parks are provided to improve the air and give places for outdoor rest to the population.

Sewage Disposal. Disposal of waste products, especially sewage, is an important problem in most cities. The general custom has been to allow the sewers to empty into streams or lakes, but this practice has many objections, especially as cities grow larger and more numerous.

Streams thus used are polluted, the odor is sometimes offensive, fish are killed, and the water becomes dangerous for bathing or drinking. When garbage is taken out to sea or when sewage is discharged, even at a distance from shore, pollution

occurs and bathing is dangerous, due to the material that is washed back by the waves.

The modern and safe way of handling the problem is by means of sewage disposal plants, where the waste is treated chemically and acted upon by certain useful bacteria. Its odor and dangerous character are thus destroyed and it can safely be discharged into streams or used for fertilizer. Much valuable food for the soil is wasted in our present methods of sewage disposal. All this organic matter ought to be replaced upon the land that produced the food stuffs for the city, instead of being thrown into the streams and washed out to sea to pollute the waters.

Disease Prevention. It is in this department that modern hygiene has made its greatest progress. We now provide free hospitals, clinics, and dispensaries where the sick may receive treatment. We have visiting nurses, city physicians, and school health examinations to make sure that all who need help, shall receive it. Stringent laws regulate vaccination, quarantine, and disinfection of infected premises. Coughing, sneezing, and spitting are forbidden where they endanger the public health, and the public towel and drinking cup are, fortunately, things of the past.

Campaigns of education by printed matter, pictures, school instruction and lectures, have been undertaken by city, state, and national governments, as well as by life insurance companies and institutions like the Rockefeller Institute for Medical Research.

As a result, we are becoming a longer lived and healthier nation. Dirt, vermin, and disease are recognized as enemies and are being removed or controlled.

Factory and Housing Conditions. The strongest constitutions cannot endure dark, ill-ventilated or crowded homes and factories. Laws, inspection, and information are being combined to bring about better conditions.

In most States child labor is forbidden or restricted, housing conditions are looked after to some extent and fire protection is usually well provided.

To carry out these many lines of civic biology, cities and towns usually have a Board of Health, inspectors, and the assistance of the police. In large cities public laboratories are maintained where examinations of food, milk, water, and disease cultures are made. There may be one or more city physicians city chemists, and visiting nurses who help enforce and carry out the regulations.

The street cleaning and fire departments perform their obvious parts as well as the city engineers who look after the drains sewers, and parks.

The Federal government devotes much of the work of the Department of Agriculture and the Department of Commerce and Labor, to matters pertaining to national health and the conservation of natural resources. They distribute quantities of valuable literature, and carry out investigations along varied lines of civic biology.

Patent Medicines. The consumption of patent medicines costs the people of the United States $300,000,000 per year. This would be well enough if the people were benefited by their use, but this is rarely the case. On the other hand, most of them are fakes, some are positively dangerous, all are outrageously expensive, and in many cases their use delays proper treatment, till too late.

The Food and Drug law obliged them to make no claims to "cure" unless they could prove their claims and this rule has practically removed that word from their vocabulary of fiction.

No patent medicine ever *cured* consumption, nor "kidney trouble," nor catarrh, and they now are more careful in the wording of their advertisements, though many still try to convey the same impression.

"Consumption cures" are mainly opiates which lull the sufferer into false security until past all help. Tonics and sarsaparillas formerly depended upon alcohol for their effect. "Soothing Syrups" for helpless babies may be opium or morphine mixtures and frequently lay the foundation for drug habits in later life, if indeed the baby is not "soothed" into the sleep that knows no waking.

Headache remedies often contain heart-depressing drugs which deaden the pain but do not remove the cause, of which the pain was merely a warning.

Catarrh cures were usually cocaine or opium mixtures and often led to drug addiction; under recent laws they are much restricted.

The Food and Drug Law does not forbid the sale of these medicines but it does oblige the maker to do two things:

1. He must put on the label the amounts of alcohol, morphine, cocaine, opium, or other harmful drug which his medicine contains.

2. He must not "make any false or misleading statement" as to the virtues of his particular "remedy."

This is one of the chief values of the law and applies to food stuffs as well as medicines, so the only way to obtain the protection which the law affords, is by reading the labels before you buy.

One can often judge of the character of a newspaper or magazine, from the number and kind of patent medicine advertisements which it carries. A reputable periodical will not now open its columns to the false and misleading claims which some medicine manufacturers offer. Look over the literature that comes to your home and draw your own conclusions.

COLLATERAL READING

Principles of Health Control, Walters, pp. 373–396; *Civics and Health*, Allen, entire; *The Human Mechanism*, Hough and Sedgwick, pp. 477–540; *A Handbook of Health*, Hutchinson, entire; *Community Hygiene*, Hutchinson, entire; *Town and City*, Jewett, entire; *Sanitation Practically Applied*, Wood, see index; *Handbook of Sanitation*, Price, see index; *Sanitation in Daily Life*, Richards, look through.

Bulletins of U. S. Department of Agriculture, State Departments of Health, Rockefeller Institute for Medical Research, City Health Departments.

SUMMARY OF CHAPTER XLVII

CIVIC BIOLOGY

1. Our responsibility for welfare of others.

2. The needs, as shown by health conditions.

3. Results of modern methods of hygiene.

4. Food control.

a. Food
b. Water.
c. Milk.
d. Food and Drug Law.

5. Sanitation.

a. Sewage and garbage disposal.
b. Building restrictions.
c. Care of streets, parks, and trees.

6. Disease prevention.

a. Free school care for the sick.
b. School examinations and clinics.
c. Laws as to spitting, etc.
d. Education in hygiene and cleanliness.
e. National, state, and individual publications and help.

7. Factory and housing conditions.

a. Laws as to conditions and hours of work.
b. Laws as to child labor.
 (1) Compulsory school attendance.
c. Various boards and inspectors to carry out work in civic biology.

8. Patent medicines.

CHAPTER XLVIII

THE ECONOMIC BIOLOGY OF PLANTS

Vocabulary

Economic, pertaining to man's use.
Solvent, a substance used to dissolve others.
Utilize, to use.

Economic biology deals with the relation of living things to man, either for use or for harm. The "economic importance" of a plant or animal does not mean merely its *value* to man, but also includes any way in which it may damage him. Usually the uses outnumber the injuries, but do not forget that both are included.

General Uses of Plants.

1. To supply foods for man and animals.
2. To aid in returning nitrogen compounds to the soil.
3. To regulate drainage of water (forests).
4. To supply oxygen and remove carbon dioxide in photosynthesis.
5. To provide fabric fibres (cotton, linen, hemp).
6. To provide fuel (wood, peat, and coal).
7. To provide paper materials.
8. To provide timber, cork, rubber.
9. To provide tanning materials (hemlock, oak, and other barks).
10. To provide dye stuffs.
11. To provide drugs and medicine, alcohol.
12. To provide turpentine, wood alcohol, acetic acid.

To balance this long list of uses for plant products, there are but few ways in which they ever harm mankind. Some of these have been studied in Chapter XVII.

Of course *bacteria* head the list of harmful plants, in that they cause many diseases, but do not forget that most bacteria are

useful and that some disease germs are not bacteria at all, but are protozoan animals. Other *fungi* also cause harm to man's crops and foods; among these are the rusts, molds, smuts, and mildews, which have also been studied before. Some plants are *poisonous* and do a little harm in that way; among these may be mentioned certain mushrooms, poison ivy, water hemlock, etc. In cultivated land, many wild plants cause harm by interfering with crop growth. We call these "*weeds*" and they demand much labor and expense for their control.

Courtesy of "Nature Magazine."

FIG. 170. Poison ivy, a dangerous plant. Learn to recognize these leaves and avoid trouble.

We shall now take up some of the economic applications of plant biology in detail.

Oxygen Supply. The importance of plants as a source of oxygen and in removal of carbon dioxide has been explained in Chapter XIII but cannot be over-emphasized. Without this action of plants, the supply of oxygen would be exhausted and no animal life could exist.

Nitrogen Fixation. The return of nitrogen compounds to the soil by the action of certain bacteria has also been mentioned (Chapter XVII) and is one of the ways in which its fertility is maintained, while the natural decay of the plant tissue also aids in this same process.

Control of Drainage. The regulation of drainage is brought about by the forests, which act like enormous sponges, soaking up the rains and letting the water filter slowly through the soil, instead of rushing off in floods, as it does when heavy rains fall on barren regions.

Foods. *Cereal Grains.* Of all plant parts used for food by man, seeds are the most important, and among them the cereal grains easily take first place.

From Sargent.

FIG. 171. Wheat, a valuable member of the grass family. The picture shows the whole plant and details of the head and separate flowers.

These cereals (whence the name?) are the fruits of various grasses and include wheat, corn, rice, rye, barley, oats, etc. They constitute the most important group of food stuffs used by man or other animals. In their composition these grains contain but little water, hence they "keep" well, and store

considerable food in a small bulk: they are all rich in starch. Wheat contains much protein (gluten) and corn is well supplied with oil, of which the other grains contain but little.

The protein of wheat makes its flour produce a sticky batter resulting in the spongy "light" loaf which no other grain will yield. Macaroni is another wheat product that depends on this fact for its wide use. The lack of fat in most cereals is made up for by using butter, milk, or cheese with them when possible.

All cereals, especially if the whole grain be used, supply phosphorus, sulphur, potassium, calcium, magnesium, and sodium compounds which are so essential to proper rations. (See Chapter XXXIX.) They are easily cultivated, ripen quickly, yield largely, and so constitute one of the first and most important crops raised by man. The history of the cereals is the history of the human race. Wheat is found embedded in Egyptian brick five thousand years old. Other grains are found among the relics of the Swiss Lake dwellers, perhaps much older, while the Chinese have cultivated rice for over four thousand years. Corn was used in America long before the dawn of history.

Kinds of Cereals. *Wheat* is the most important vegetable food in Europe and America. The United States leads in its production with Russia in second place. Not only does it provide the white bread of the world, but macaroni, spaghetti, vermicelli, etc., are also wheat products.

Rice feeds more people than any other grain, being the chief cereal of China, India, and southern United States. It is estimated that one-half the population of the world depends upon it.

Corn was one of the first cereals to be used by savage tribes because it is easily cultivated in almost any climate; United States also leads in the production of this grain. Not only is it valuable as food for men and animals, as meal, canned or fresh, but starch, corn syrup, glucose, oil, and gluten foods are among its products.

Oats will thrive in colder climates than any other grain. It is

the principal cereal of Scotland, Norway, Sweden, and Iceland, and is used for food and fodder in other temperate regions.

Barley also endures cold but will thrive in warmer regions as well. It was formerly a valuable food, but is now more used for fodder and for malt to make beer.

Courtesy of Connecticut Agricultural Experiment Station.

FIG. 172. A field of corn, the great American cereal.

Rye will grow in poorer and rougher soil than any other grain and Russia leads the world in its production. It makes the common "black bread" of Austria, Germany, Russia, and Sweden.

Buckwheat, despite its name, is not a true grain and while pleasant in flavor, its flour has little food value; it is a native of northern Asia and will grow in poor soil in temperate climates.

Legumes. Next in importance to the cereals among the seeds used for food are the *legumes* (peas, beans, and lentils) all members of the pea family to which also belong the clover, locust, etc.

The legumes are very valuable foods, rich in protein and starch, have little water or oil and hence keep well, though their protein (legumin) is not so easily digested as animal forms.

Nuts. *Nuts* are larger and richer in protein and oil than grains or legumes but are less used for food, because the crop

From Sargent.

FIG. 173. Peanut, a legume that is called a nut.

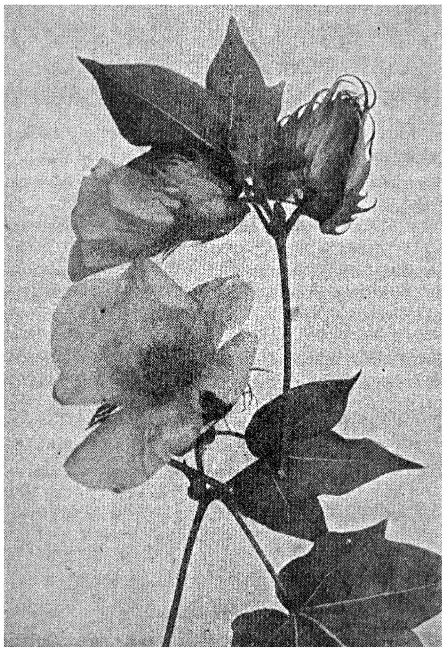
A, lower part of a plant showing the leaves and flowers above ground, and ripening nuts and roots below; the surface of the ground indicated at *el*. *B*, a flower cut vertically. *C*, a ripe nut cut lengthwise to show the two seeds. (Tanbert.)—The plant is an *annual*, i. e., it completes its life from seed to seed in one year; flowers orange-yellow. Soon after pollen has come upon the stigma, the stamens and corolla are shed and the ovary is carried out beyond the calyx by a stalk which becomes 2–3 inches long, and, bending downwards, soon buries the little ovary in the ground. Once buried the ovary ripens into the familiar pod-like nut. If it fails to get buried the ovary withers.

takes too long to mature and is too bulky to store. Nuts also contain so much oil that they do not keep nor digest well.

The chestnut has little oil and more starch than other varieties. It is used for food in Europe as are also walnuts and

pecans, to some extent. The people of the tropics use coconuts, peanuts, and Brazil-nuts because cereals do not thrive in such climates.

Other Seed Foods. *Coffee* is a very valuable seed product, though not strictly a food. It is the seed of a fleshy berry



Courtesy of U. S. Dept. of Agriculture.

FIG. 174. Cotton in blossom.

borne on a shrub about 15 feet high. Coffee belongs to the same family as quinine and madder (a dye plant) as well as our common bluets, partridge berry, and bed straw. It grows only in tropical regions, mainly in Brazil, Arabia, and the East Indies.

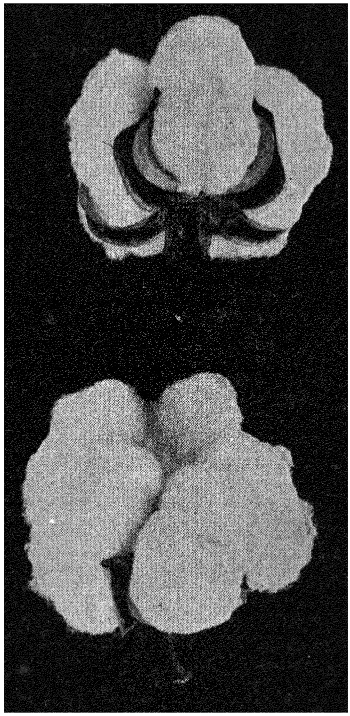
Cocoa is valuable as a food, though less used than coffee. It is obtained from the seed of a small tropical tree growing in

South and Central America, Africa, and Ceylon. From the "cocoa bean," as it is called, are made cocoa, chocolate, and cocoa butter. It must be observed that cocoa has nothing whatever to do with the coconut which is a palm fruit while still another plant (coca) furnishes from its leaves the dangerous drug cocaine.

Notice the different spellings: COCOA, beverage, chocolate; COCONUT, food product, palm; COCA, plant, cocaine.

Another valuable group of seed products includes many *spices*, such as mustard, nutmeg, mace, anise, celery, and caraway. Castor oil and strychnine are important medicines obtained from seeds.

Many seeds produce useful *oils* among which should be mentioned cotton-seed, peanut, and almond, which are used for food; cocoa and corn oils for soap and linseed (flax) oil for paints.



Courtesy of U. S. Dept. of Agriculture.
FIG. 175. Cotton bolls.

In all these important foods that man obtains from seeds, he has been using the store of nourishment intended for use by the embryo plant. Most seeds "keep" well and have a very concentrated store of food, an adaptation for reproduction of the plant, which man has utilized for his own benefit.

Root Food Materials. *Roots* furnish a large part of one of man's most valuable foods, namely, sugar. Sugar beets now

produce over half the world's supply of "granulated" or "white" sugar; the rest comes from the stem of the sugar cane. Other products from the beet-sugar industry are potash for glass-making, fodder for cattle, and waste for fertilizer.

From Sargent.

FIG. 176. Coconut Palm. (Baillon.) The columnar trunk rises to a height of 60–90 ft. and bears bright green leaves 18–20 ft. long.

Among our common garden vegetables we have the roots of beet, turnip, carrot, radish, parsnip, and sweet potato (not the common potato, which is an underground stem).

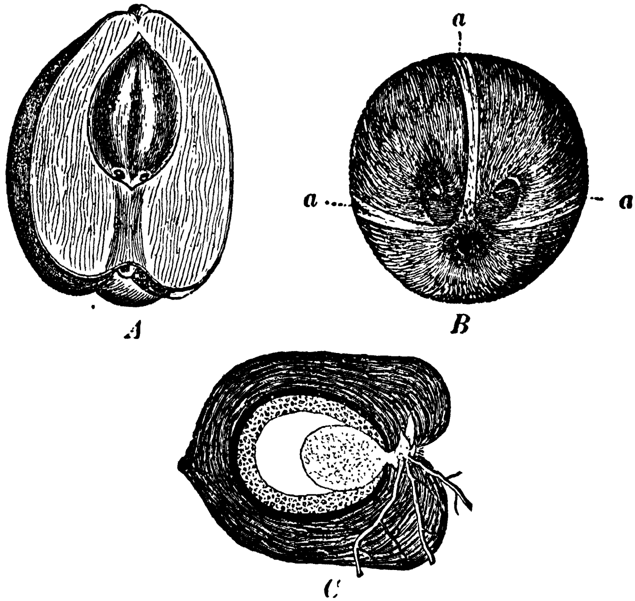
Ginger, licorice, rhubarb, marshmallow, tapioca, and aconite are all root products, used for food or medicines.

Stem Food Materials. *Stems* provide many forms of food among which the sugar cane takes the lead and the potato comes next in order.

Potatoes are used directly as food, and also furnish starch and dextrine, the latter being the gum used on stamps, labels, etc., and also for finishing many kinds of cloth. The pith of a certain palm stem furnishes sago starch and pearl tapioca while arrow-root starch is from the underground stem of a West Indian plant and is the most easily digested of all starches. Cinnamon bark, asparagus, camphor, and witch hazel are food and drug products also derived from stems.

Leaf Food Products. We usually think of leaves as fodder for animals (grass, hay, etc.), but notice the list of those that we commonly use ourselves. We must include the garden

vegetables, cabbage, lettuce, celery, spinach, rhubarb, parsley, onion, cress; the flavors of mint and wintergreen; tea and tobacco; and the drugs, cocaine and belladonna. Although



From Sargent.

FIG. 177. Coconut.

A, fruit, showing husk cut vertically through the centre, revealing the hard shell of the nut.

B, nut viewed from below, showing the lines (*a*, *a*, *a*) along which the three pistils are united; and between them the three germ pores, from the lower one of which, ordinarily, the single germ emerges in sprouting.

C, lengthwise section through the fruit sprouting; notice the thick husk, into and through which the young roots grow, the hard shell of the nut (black), within which is the layer of solid seed food (coarsely dotted), and the liquid food or "milk" (white) into which the enlarging cotyledon or seed leaf (finely dotted) pushes its way and acts as an organ of absorption. (Warming.) The husk is smooth and grayish brown, and is largely composed of coarse, tough fibres.

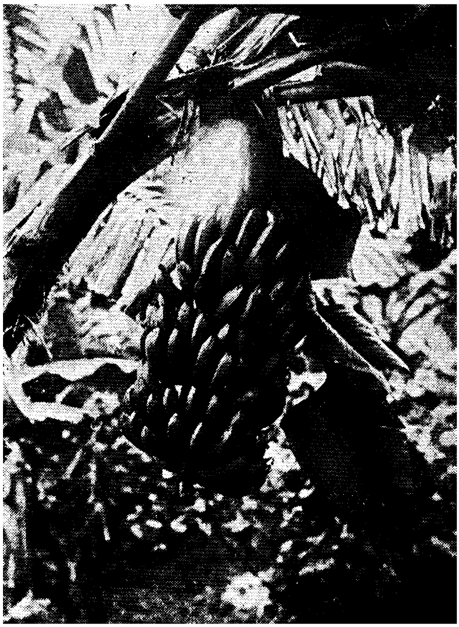
leaves have little real nourishment in them because not intended as storage places for food, yet they are necessary to man's diet, since they supply many of the mineral salts, especially iron and potassium compounds,—and also vitamins, all of which are essential to health.

From Sargent.

FIG. 178. Sugar cane. Grass Family. Plant in flower. *A*, *B*, *C*, flower structure. Perennial, attaining a height of 13 ft.

Flowers. *Flowers* we seldom eat, but cauliflower is one exception, and cloves and capers are both flower products.

Fruits. *Fruits* furnish an extended list of foods for man, We classify them as follows: pomes, such as apples, pears. and quinces; stone fruits, like the peach, plum, cherry, apricot, and prunes; citrus fruits, orange, lemon, grape fruit; simple



Courtesy of U. S. Dept. of Agriculture.

FIG. 179. Bananas as they grow, "wrong side up."

berries, currant, grape (raisin), blueberry, tomato; compound berries, such as raspberry, strawberry, and blackberry; gourd fruits, pumpkin, squash, cucumber, melon, and citron; miscellaneous, banana, date, olive, peppers, vanilla, allspice.

Hops and opium are also fruit products and, though not foods, may be mentioned at this point. Like leaves, fruits are not often very concentrated foods, but supply sugar, acids, vitamins, and mineral salts which are very necessary to a proper diet.

Foods from the Spore Plants. The spore plants furnish but little toward man's food, mushrooms being the only ones commonly eaten, and of these many are dangerous and the best only one-sixth as rich in protein as meat.

Iceland moss is a curious lichen sometimes used in jellies and

From Sargent.

FIG. 180. Sea Island cotton plant. Mallow family, $\frac{1}{4}$ natural size. Native home, West Indies.

medicines. Though we do not eat them to any extent we must not forget that we could not do without spore plants, such as yeast and certain bacteria that help in preparing such important foods as bread, butter, and cheese.

Fibre Plants. *Cotton* is the most valuable plant fibre. It is an outgrowth of the outer coat of the cotton-seed, intended to aid in its dispersal, and consists of strong, twisted fibres

very well adapted for spinning. Not only is cotton made into thread and cloth, but into batting, surgical dressings, paper, celluloid, gun cotton and artificial silk.

Flax which is the bast fibre of the bark of the plant of that name, ranks next to cotton in value. From it are made linen

From Sargent.

FIG. 181. Flax. Plant in flower. Annual, about 2 ft. tall; leaves smooth; flowers light blue; Native home, Southeastern Europe and Asia Minor.

thread, cloth, and lace; canvas, duck, carpet warp, oil cloth, fine paper, and parchment. It is harder to prepare than cotton and is grown chiefly in North Europe.

Jute is the bast fibre of certain plants of India; it is not so fine

nor durable as linen but is made into burlap, sacking, webbing, and cordage.

Hemp is the bast fibre of a member of the nettle family and is cultivated largely in Europe for its fibre uses, while in Asia an intoxicating drug is prepared from the same plant. Hemp is coarse, but stronger than flax and is used for sail cloth, cordage and oakum.

Manila fibre is obtained from the leaves (veins) of a banana-like plant of the Philippines. From this are made the best ropes, binder twine, bagging, and sail cloth.

Coconut fibre comes from the outer husk of the coconut and is used for cordage and for the familiar brown door mats.

Other uses for vegetable fibres are in the manufacture of cheap brushes, brooms, matting, packing and upholstery.

Fuels. The next topic in our list of plant uses is fuel. While this is of enormous importance, it needs little explanation, as all are familiar with coal and wood and must know that gas is made from the former. *Peat* is an important fuel in some parts of Europe and consists of the partly decomposed and compressed peat moss, similar to that in which florists pack their plants. From coal are also obtained a vast number of dyes, medicines, explosives, and other products which will be studied in chemistry.

Paper Materials. All forms of paper are made from plant material, chiefly from wood fibres of spruce, poplar, and similar trees. Cotton waste, linen, and jute are important paper materials while in Japan the young stems of the paper mulberry are used.

Timber. The matter of timber structure and of forest products in general will be taken up later. The uses of timber are so numerous that only a few can be mentioned; among these are:

General building	Furniture
Ships	Boxes
Vehicles	Bridges
Pavements	Poles
Railroad ties	Mine timbers

Willow, ash, and hickory are split for making baskets, chairs, and hats; rattan and wicker work are from similar sources. Pine and spruce furnish excelsior for packing. Cedar supplies our pencils, and mahogany and other fine woods are cut into veneers for cabinet work.

Two other very valuable tree products, though not timbers, are cork and rubber. Cork is obtained from the bark of the cork oak which grows largely in Southern Europe and is used not only for stoppers, but to make linoleum, life preservers, packing, artificial limbs, handles, etc.

From Sargent.

FIG. 182. Harvesting cork. (Figuier.)

Rubber is made from the milky juice of several tropical trees of South America and Asia; its numerous uses are familiar to most of us.

Tanning Materials. The principal tanning materials are obtained from the bark of the oak, hemlock, willow, birch (Russia leather), chestnut, and the South American quebracho.

Dyestuffs. Vegetable dyes have become much less important since the development of the coal tar or aniline colors, however indigo, logwood, and gamboge may be mentioned. The indigo

plant grows in India and Java and furnishes the familiar blue dye; logwood grows in Central and South America and furnishes red and black dyes; gamboge is a yellow dye grown in Siam.

Drugs. Several drug products have been mentioned elsewhere so that merely a brief list will be given here:

Gums: Camphor (China), Arabic (Africa), Tragacanth (Asia).

Witch hazel from leaves and stems of a native plant.

Opium from milk of Chinese and Indian poppy fruits.

Cocaine from coca leaves (Peru).

Quinine from chinchona bark (Peru).

Strychnine, atropine, and nicotine are important plant drugs.

Alcohol is one of the most important plant drug products; it has a multitude of uses other than as a beverage. It is utilized in all chemical industries, as a solvent, fuel, preservative, in non-freezing mixtures and in many other useful ways.

Alcohol is made by the action of yeast ferments on several kinds of sugars. Apples, rye, corn and barley, grapes and molasses are sources of alcohol.

All of these and some waste sugar liquors are fermented and distilled for this purpose.

Distillation Products. The last topic in our list of plant uses includes several products from distillation of wood or pitch. Crude turpentine is the pitch of certain kinds of pine found in our Southern States, France, and Russia. From it the common turpentine is made by distillation and rosin is left as a residue. Turpentine is used in paints, and rosin in all kinds of varnish, soaps, cements, and soldering. Wood alcohol, acetic acid, and charcoal are all made by distilling any kind of wood in large closed vessels. It is an important industry in many wooded regions.

COLLATERAL READING

Elementary Studies in Botany, Coulter, pp. 342–418; *Botany for Schools*, Atkinson, pp. 392–420; *The World's Commercial Products*, Freeman and Chandler, entire; *Plants and their Uses*, Sargent, entire; *Domesticated Plants and Animals*, Davenport, entire.

SUMMARY OF CHAPTER XLVIII

THE ECONOMIC BIOLOGY OF PLANTS

1. Uses of plants.

2. Harmful plant forms.

a. Some bacteria (disease).
b. Some fungi (destroy crops, timber, etc.).
c. Poisonous plants.
d. Weeds.

3. Plants and oxygen supply.

4. Nitrogen return.

5. Control of drainage.

6. Sources of food supply.

a. Seed products.

Plant	*Location*	*Uses*
1. Cereals.		
Wheat	U. S., Russia	Bread, macaroni, etc. Principal food of white races.
Rice	China, India	Feeds half the world.
Corn	North America	Food, fodder, starch, oil, alcohol.
Oats	North Europe	Food, fodder.
Barley	Central Europe	Fodder, beer, food.
Rye	Europe	Dark bread, whiskey.
2. Legumes.		
Beans, Peas, Lentils	Generally cultivated	Important as protein foods.
3. Nuts.		
Chestnut	South Europe	Food, starch, little oil.
Coconut	Tropics	Food, fiber.
Peanuts	America	Food, oil, butter.
4. Various seeds.		
Coffee	Asia, S. America	Beverage.
Cocoa	S. and Cent. Am.	Beverage, chocolate, butter.
Mustard, Nutmeg, etc.	Various	Spices and flavors.
Cotton-seed, Peanut, Almond, Flax, cocoa	Various	Oils for food, soap, paint.

b. Root products.

Plant	*Location*	*Uses*
Sugar beet	Europe, U. S.	Sugar, potash, fertilizer.
"Vegetables" Beet, carrot, turnip, parsnip	Various	Food, supplying starch and minerals.
Sweet potato	Southern U. S.	Food.
Ginger	India	Spice.
Licorice	Mediterranean countries	Flavor, medicine.
Rhubarb	Various	Medicine.
Aconite	Europe	Medicine.
Cassava (tapioca)	Africa	Food starch.

c. Stem products.

Plant	*Location*	*Uses*
Sugar cane	U. S., India, West Indies	Food, sugar, molasses, alcohol.
Potato	U. S., Europe	Food, starch, dextrine.
Sago palm	East Indies	Starch.
Arrowroot	West Indies	Starch.
Asparagus	Various	Food.
Cinnamon	Ceylon	Spice from bark.
Camphor	China	Gum for medicine, celluloid, etc.

d. Leaf products.

Plant	*Location*	*Uses*
Onion, cabbage	Various	Food (mineral salts).
Lettuce, rhubarb	"	"
Mint, wintergreen	Various	Flavors.
Tea	India, China	Beverage.
Tobacco	Various	Smoking and chewing.
Coca	S. America	Drug (cocaine).

e. Fruits.

Pomes, apple, pear

Citrous fruits, orange, lemon

Comp. berries, strawberry, etc.

Stone fruits, cherry, plum, peach

Berries, grape, currant, tonato.

Gourd fruits, squash, pumpkin, cucumber.

Various fruits, banana, date, olive, vanilla, hops, poppy (opium).

f. Spore plant products.
   (1) Mushrooms.
   (2) Iceland moss.
      (a) Used for jelly.
   (3) Yeast.
      (a) Used in making bread.
   (4) Bacteria.
      (a) Used in making butter and cheese.

7. Fibre plants.

Plant	*Location*	*Uses.*
Cotton	India, Egypt, United States	Cloth, paper, explosives, batting, dressings, thread.
Flax	North Europe	Linen, canvas, paper, lace.
Jute	India	Burlap, sacking, cordage.
Hemp	Europe	Cordage, sail cloth, oakum.
Manila fibre	Philippines	Rope, twine, sail cloth.
Coconut fibre	Africa	Mats, brushes, upholstery.

8. Fuels.

a. Wood.
b. Charcoal.
c. Peat.
d. Coal.
e. Gas.

9. Paper materials.

a. Spruce, poplar, etc.
b. Cotton and linen waste.

10. Timber and related products.

a. Lumber. b. Cork. c. Rubber.

11. Tanning materials.

a. Barks.
   (1) Hemlock. (2) Chestnut. (3) Willow. (4) Quebracho.

12. Dyestuffs.

a. Indigo. b. Logwood. c. Gamboge.

13. Drugs.

a. Alcohol.
b. Opium.
c. Cocaine.
d. Quinine.
e. Camphor.

14. Distillation products.

a. Charcoal.
b. Wood alcohol.
c. Acetic acid.
d. Turpentine.

CHAPTER XLIX

THE ECONOMIC BIOLOGY OF INVERTEBRATES

Vocabulary

Polyp, the coral animal, which is *not* an "insect."
Succulent, juicy.
Bivalves, two-shelled animals, such as clams.

We shall take up the economic relations of animals in the same way as we have plants, giving the general uses and harm done, and then taking up each large animal group somewhat in detail. The subject is so broad that many books have been written on the economic relations of insects, birds, or mammals alone, so we will be required to consult reference books for fuller information. Try especially to find as many examples of each case as possible, particularly animals which are familiar.

General Uses of Animals.

1. To supply food (flesh, eggs, milk, etc.).
2. For transportation (horse, ox, camel, dog).
3. To provide fabric fibres (silk, wool).
4. To provide fur (seal, mink, otter).
5. To provide leather (cattle, sheep, horse, etc.).
6. To provide feathers.
7. To provide various products, such as ivory, horn, glue, gelatine, hair, etc.
8. To aid in pollination and seed dispersal.
9. To act as scavengers.
10. To aid in destroying harmful animals and plants.

Harmful Kinds of Animals. From this list it is evident that man owes about as much to animals as he does to plants. There are, however, a few harmful exceptions.

Certain protozoa cause disease (see Chaps. XVIII and XXV) and some parasitic worms (Chap. XX) also do considerable harm. Many insects live upon the plants that man also uses for

food and in this way cause serious destruction to crops, while others transmit disease (Chap. XXV). To a very small extent "wild animals" harm man directly and also destroy some of his domestic animals, but this is of comparatively little importance.

Economic Value of Animals. In dealing with the economic importance of animals we shall take them up by groups beginning with the simplest first, namely the protozoa.

Protozoa. These minute one-celled forms are of vast importance to man insomuch as they are the source of food for higher animals and these in turn finally provide man with nourishment, by way of such important sources of food as clams, oysters, crustaceans, and fishes, many of which find, in protozoa, their chief food supply.

Certain protozoa develop minute shells and the deposits of these tiny skeletons have produced great layers of chalk and other rock, which form important land areas such as the Dover cliffs in southern England. Some of the pyramids are made of stone formed from protozoan deposits.

Many protozoa perform valuable service as scavengers, and, since they are mostly aquatic, aid in keeping our water supply free from filth. On the other hand, some diseases are caused by protozoa, among which are malaria, yellow fever, dysentery, and probably scarlet fever and smallpox. (See Chap. XVIII).

Sponges. From the next higher group, the sponges, man obtains the various forms of the common "sponge." The sponge is really the horny skeleton of the sponge animal, from which the jelly-like flesh has been removed by rotting and washing. Sponges grow attached to the sea bottom in various warm regions, such as the Mediterranean and Red Seas, and Florida and West Indian waters. The best come from the Mediterranean. A live sponge is a roundish smooth mass, rather dark brown in color, provided with many pores for passage of water, and having about the consistency of a piece of beef liver.

They are collected by divers or by dragging hooks, piled on shore till the flesh rots off, washed, dried, sorted, and sometimes bleached. The world's annual sponge crop is worth about $4,000,000.

Cœlenterates. The cœlenterates include many curious and beautiful animals such as the hydras, hydroids, jelly-fish, corals, and sea-anemones, but the only forms directly of use to man are the corals. Colonies of these tiny animals, called coral polyps, secrete so much limestone in their body walls that they form the coral reefs which make up large parts of some continents, notably Australia and the Pacific islands. Other coral reefs of very ancient times now form important beds of limestone like the corniferous ledges that cross central New York. The red coral used for jewelry is another product of this group, found principally in the Mediterranean.

Echinoderms. The echinoderms include the starfish, sea-urchin, and sea-cucumber. Starfish are an enemy of the oyster and a special effort is made to keep them out of oyster beds. The Chinese and West Pacific peoples use the sea-cucumbers for food, as soup, and consider them a great delicacy.

Worms. As already stated in our study of worms (Chapter XX), we owe to the humble earthworm a heavy debt for his services in keeping the soil in fertile condition; and we must not forget that without this work we should probably have much difficulty with our agriculture. On the other hand, the parasitic worms, such as tape-worm, hook-worm, trichina, and other intestinal forms, cause serious disease or death in man. Similar forms, the flukes, infect our domestic animals, especially sheep, which they attack by way of the liver and cause the death of hundreds of thousands every year.

Molluscs. Primitive man, before he knew the use of fire, depended upon raw molluscs for much of his food, as the enormous shell heaps remaining to this day testify. Even yet we look upon oysters, clams, mussels, and scallops as useful foods or luxuries, depending on how far we live from the seacoasts where they are obtained. In all, except the scallops, we eat the whole body, the bulk of which consist of the foot, liver, and reproductive glands. What we hear called the "ears" are really the muscles that held the shell together and it is this muscle *only* which we eat in the case of the scallop.

Clams are found along our whole Atlantic coast; oysters are

abundant south of Cape Cod with Chesapeake Bay as the centre of the industry, having the largest production of any region in the world. The Pacific coast and foreign shores also furnish these succulent bivalves, but even so, Chesapeake oysters are in demand in the best markets of Europe. The oyster yields the most valuable water crop in existence. It is the leading fishery product in fifteen different States. Aside from their value as food, molluscs furnish us with "mother-of-pearl" for buttons, handles, and ornaments, with crushed shell for chicken feeding, and with the precious pearl of the jewelry store.

These latter are found chiefly in pearl oysters (not the edible species) and are caused by the entrance within the shell of a grain of sand or the irritation of a parasitic worm. This makes the oyster secrete layer after layer of shell substance, to cover the offending particle, much as the hand protects itself from irritation by growing a callous layer. The most valuable pearls are found in the Persian Gulf and on the coasts of Ceylon. Fresh-water clams furnish the irregular "baroque" pearls and are found largely in the Mississippi and its branches.

Shells have always been used for ornaments and formerly passed for money as well, the "cowrie" of Africa and the "wampum" of our Indians being two examples. Wampum consisted of beads cut from the colored parts of clam shells.

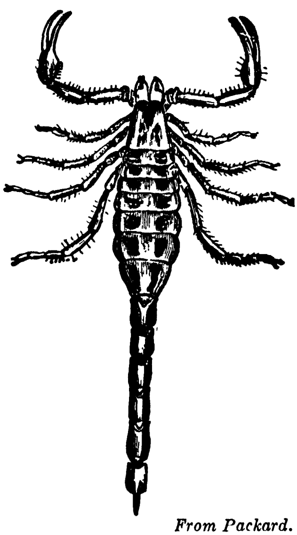
Snails and slugs are another group of molluscs which, especially in France, are valued as food. They do considerable harm in gardens where they eat young seedlings and leaves. The shiny trails so often seen on sidewalks are left by the slugs in their travels.

A near relative is the abalone of the California coast, whose beautiful rainbow colored shell is used for ornaments and inlaying work.

The third group of molluscs is called the cephalopods and includes the squid, cuttle fish, and octopus. Man uses squid for fish bait, and obtains from the cuttle fish the true "sepia," a brown ink-like pigment which the animal squirts out to hide itself when attacked. The "cuttle bone" familiar in the canary cage is the internal shell of this same mollusc.

Crustacea. The larger crustaceans, lobsters, crabs, shrimps, and prawns are valuable sources of food to man; the smaller forms are equally valuable as food for fish, and all are useful scavengers. Of all these the lobster is most valuable. From twenty to thirty million are annually caught along the coasts of New England and Canada and the business is carefully regulated by law to prevent their destruction by over fishing. "Soft shell" crabs are merely the ordinary blue crabs, taken just after moulting and before their new shells have formed.

Barnacles are curious crustaceans which attach themselves to rocks, piles and even to the bodies of whales and bottoms of ships. In the latter place they interfere with easy sailing and have to be removed.



From Packard.
FIG. 183. Carolina scorpion.

Crayfish sometimes burrow through dykes or levees, letting water leak through and starting serious breaks.

Arachnida. Spiders as a whole are distinctly beneficial because of their destruction of flies and other insects; their bite is seldom serious to man, though some large tropical kinds can kill small birds. Scorpions are found in Southern United States and tropical America and Africa; their abdomen ends in a venomous sting, which, while painful, is seldom fatal to man.

"Daddy-long-legs," which belongs to this group, is a very useful citizen because he feeds almost entirely on plant lice.

Mites and ticks are degenerate parasitic forms which live on the blood of mammals such as the dog, cattle, and man. The itch is a disease produced by a mite, but, thanks to the popularity of soap, it causes little trouble.

Insects. The economic relations of insects are so important and complicated that we can only summarize them here. Refer

to any of the books on "economic zoölogy" to get a full idea of their importance. Over half of all insects are harmful, 250 species attack the apple, grape, and orange, alone.

As to their harmful activities, they

1. Destroy grain, vegetables, and fruit crops.
2. Convey many kinds of disease (flies and mosquitoes).
3. Injure domestic animals (flies and mosquitoes, etc.).
4. Destroy buildings, clothing, etc. (white ants and "moths").
5. Annoy and injure man by bites and stings.

Their total damage in United States is over $2,000,000,000 per year.

On the other hand, we owe to the insects many useful processes and products such as

1. Pollination of flowers of valuable plants.
2. Acting as scavengers (maggots, beetles).
3. Killing injurious insects (lady bugs which eat scale insects and ichneumon flies that destroy tree borers).
4. Furnish silk (silk moth cocoon).
5. Furnish honey and wax (bees).
6. Furnish dye (cochineal red from a scale insect).
7. Furnish shellac (gum secreted by a scale insect).
8. Furnish ink material (gall insects).

The following are some of the common injurious insects which you should learn to recognize so as to destroy them whenever possible:

Fruit Tree Pests

Tent Caterpillar. Makes web nests in apple and cherry trees. Caterpillar dark, with white stripe; moths light brown, with white stripe on front wings; eggs in belts around small twigs. Treatment: collect and burn egg masses; destroy nests; spray with poison early in the spring.

Codlin Moth. The familiar "apple worm" is the larva. Eggs laid on young apple just after petals fall, the larva hatches in a few days and feeds around the core, making the "wormy" apple. Treatment: spray with poison just after petals have fallen and before the larva can get inside the fruit or calyx. This insect costs New York State $3,000,000 per year.

Scale Insects. Small circular or oval scales on bark; these cover the bodies of the females under which eggs are deposited. Each scale insect sucks its nourishment from the juices of the plant and by their large numbers do great damage. Treatment: spray with crude petroleum emulsion before buds start in spring; spray with kerosene or whale oil emulsion during summer.

Aphids or Plant Lice are related to scale insects; common, small, usually green insects. Damage apple, peach, cherry, and shade trees, also many garden vegetables and flowers. Some secrete "honeydew" a fluid which ants use for food. Treatment: contact sprays.

Photograph by Slingerland. From Kellogg.

FIG. 184. Life history of the forest tent caterpillar moth. *m*, male; *f*, female; *e*, mass of eggs in ring around stem, recently laid; *g*, eggs hatched; *c*, larva or caterpillar; *p*, pupa; moths and caterpillar natural size, eggs and pupa slightly enlarged.

SHADE TREE PESTS

Tussock Moth. Handsome caterpillars with three black tufts, four white tufts, and red head. Eggs covered by frothy white substance. Treatment: destroy egg masses and use poison sprays.

Cottony Maple Scale. Masses of cotton-like scales on twigs and leaves suck nourishment from tree like all scale insects. Treatment: spray with kerosene or whale oil soap emulsions.

Borers. Larvæ of various beetles bore under the bark and into wood, loosening the bark and killing trees: the irregular grooves under old bark are caused by them. Treatment:

destroy infested trees or branches; dig out borers in fall; encourage the birds.

Gypsy Moth. Introduced from Europe. Caterpillar, hairy, two inches long. Adult, brown inconspicuous. Feeds on all sorts of leaves; very destructive to trees. Treatment: destroy egg masses with creosote; encourage birds such as oriole, vireo, cuckoo, and bluejay. Government experts are now abroad, seeking natural enemies or parasites to import as a check.

Crop Pests

Potato "Bug." A beetle whose familiar red larva does damage. Treatment: spray with poison. Arsenate of lead is better than the familiar Paris green.

Squash Bug. A *true* bug; bad odor; eggs under leaves; feeds by sucking juices. Treatment: kill adult bugs early in season to prevent egg laying; destroy eggs.

Cabbage Worm. Larva of white butterflies. Treatment: spray *young* plants with poison or dust older plants with lime; catch adults in nets.

Corn Borer. Introduced from Hungary and Italy. It is the larva of a moth. Does enormous damage to corn and many other garden plants. Spends winter as caterpillar in tunnels bored in plants. May produce two broods per year. Treatment: cut crops close; feed or burn all parts or weeds that might contain larvæ. Fall plowing and heavy rolling help.

Cotton Boll Weevil. A beetle which lays its eggs in the buds of the cotton plant. Larvae eat the buds which fall or else make stunted "bolls" useless for fibre. Winters in adult form. Damage variously estimated, perhaps 300 million dollars a year. One of the worst enemies of the cotton crop. Treatment: clean fields from refuse, plow deeply, plant early. Spraying and introduced enemies are also used.

Household Pests

Flies and Mosquitoes. (See Chapter XXV).

Buffalo Carpet Beetle. Adults one-eighth inch long; have white and red markings, may be brought in on flowers; larva

covered with bristles; eat carpets, feathers, etc. Treatment: take up carpets and spray with benzine (outdoors); fill floor cracks; use rugs.

Cockroaches and Croton Bugs. Scavengers; very prolific. Treatment: use poisons, traps, cleanliness.

Clothes' Moths. Larva of small gray moth; often in webbed cases; attack fur, woolen, etc. Treatment: frequent brushing; tight packing; use of camphor or naphthalene; cold storage.

Lice. Head and body lice are different insects; both are associated with dirty living conditions. Head lice are irritating and disgusting; body lice ("cooties") are also carriers of germs of relapsing fever, trench fever, and typhus fever. Treatment: Cleanliness. Wash head with mixture of kerosene and olive oil, then after several hours wash with soap and water; use fine comb. For body lice, bathe thoroughly and sterilize clothing by heat.

Methods of Insect Control. The life history of each insect pest has to be studied and treatment adapted to its particular habits of feeding, protection, or metamorphosis. However there are some general methods of treatment which may be mentioned.

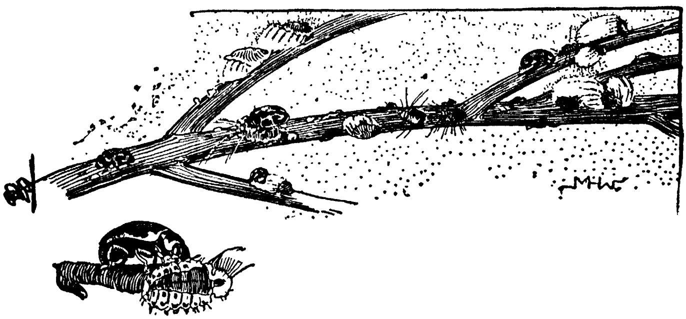
Where an insect feeds exclusively on one type of crop, planting a different crop in the infested area will sometimes starve out the pest; this is one of the reasons for rotation of crops.

Insects have three general classes of natural enemies. *First* in importance are birds, and encouraging bird life means decreasing the insect population. *Second,* many insects feed on other insects. Ichneumon flies lay eggs in the cocoon of tent caterpillars and when the fly larvæ hatch they destroy their host. The tachina fly destroys the army worm in a similar way. When the cottony cushion scale threatened the orange industry of California, a certain kind of "lady-bird" beetle was found in Australia, which was a natural enemy of the scale, and its prompt introduction controlled the spread of the scale insect. The Federal Bureau of Entomology has experts in all foreign countries, searching for the natural enemies of our imported or native insect pests.

Among the beneficial insects we should learn to recognize the

native "lady-bug," a red beetle whose larvæ feed on plant lice, and the lacewing fly, whose larvæ also favor the same diet and thus protect our plants. Another useful insect is the long-tailed Thalessa with ovipositors two to four inches in length. This insect is often feared and destroyed, whereas it lives on wood borers and is very useful.

A *third* method of insect control is by means of poisons. Some insects, such as scales and plant lice, get their food by



From Kellogg.

FIG. 185. Lady-bird beetle destroying cottony cushion scale. Upper drawing slightly enlarged, lower figure much enlarged.

sucking the plant juices. These have to be treated with contact poisons, such as oil emulsions and whale-oil soap, which will kill if they touch the insect's body. Others, like the potato bug, eat the foliage and must be killed by digestive poisons, such as arsenate of lead or Paris green, which are spread on the leaves. Tobacco dust, kerosene, and Bordeaux mixture will sometimes keep insects away from plants and are called repellents. Poisonous gases, like carbon bisulphide or hydrocyanic acid, are sometimes used in confined areas like a greenhouse or the hold of a ship. They are dangerous to use except in the hands of an expert.

INSECTICIDES

Chewing insects. May be poisoned in food.
  Larvæ of lepidoptera and coleoptera.
  Currant worm and apple worm.

Potato beetle and larvæ.
All other "worms," beetles, and "grubs."
Sucking insects. Must be killed by contact poisons.
Plant lice, aphids.
Scale insects.
True bugs (heteroptera).
For chewing insects use digestive poisons, such as:
Paris green.
Arsenate of lead.
Hellebore.
For sucking insects use contact poisons, such as:
Whale-oil soap } for lice.
Kerosene emulsion }
Lime-sulphur wash for scale insects.
For apples use
2–3 lb. arsenate of lead, 1½ gal. lime-sulphur, 50 gallons water.
For peach, plum, cherry, etc., use
2 lb. arsenate of lead, ½ gal. lime-sulphur, 50 gallons of water.
For winter spraying use one part lime-sulphur to eight water.

Fungicides

Use for blight, mould, rust, rot, or scab the following:
Bordeaux mixture.
Dilute lime-sulphur wash, as follows:
For apples, pears, etc.,
1½ lime-sulphur to 50 gallons water.
For plum, cherry, peach,
½ gallon lime-sulphur to 50 gallons of water.

COLLATERAL READING

Economic Zoölogy, Osborne, pp. 1–300; *Insects Injurious to Fruits*, Saunders, see index; *Insect Pests of Farm, Garden and Orchard*, Sanderson, see index; *Economic Entomology*, Smith, see index; *Shell Fish Industry*, Kellogg, see index; *Applied Biology*, Bigelow, Protozoa, pp. 312–316; Worms, pp. 340–345, 350; Crustacea, p. 372; Insects, pp. 390–398; *Vegetable Mould and Earthworms*, Darwin, Chap. VII; *New York State Museum Bulletin*, No. 103 and other N. Y. State Bulletins; Cornell University College of Agriculture, Bulletins Nos. 142, 234, 252, 283, 333, and others. Rural School Leaflets, list on application.

U. S. Department of Agriculture Bulletins, Farmers' Bulletins Nos. 165, 264, 275, 564, etc., Bulletin No. 492, etc., Circulars Nos. 36, 98, etc.

The above Government publications are merely a suggestion; lists can be had for the asking, and hundreds of useful pamphlets can be obtained, especially in regard to insects.

(See also Chapter XXV on "Insects and Disease.")

SUMMARY OF CHAPTER XLIX

THE ECONOMIC BIOLOGY OF INVERTEBRATES

1. General Uses of Animals.

- a. Food.
- b. Transportation.
- c. Fabric fibres.
- d. Fur.
- e. Leather.
- f. Feathers.
- g. Ivory, horn, glue, hair, gelatine.
- h. Pollination, seed dispersal.
- i. Scavengers.
- j. Destroying harmful forms.

2. Harmful Kinds of Animals.

- a. Protozoa (diseases).
- b. Parasitic worms.
- c. Insects (destroy crops, transmit disease).
- d. Wild animals (destroy man and domestic animals).

3. Economic Value of Invertebrates.

- a. Protozoa.
  - (1) Food for higher animals (clams, crustacea, fish, etc.).
  - (2) Deposit shell as chalk beds.
  - (3) Act as scavengers in water.
- b. Sponges.
  - (1) Skeleton of horny forms used as "bath sponge."
  - (2) Preparation (collected, rotted, washed, dried, bleached).
- c. Cœlenterates.
  - (1) Corals.
    - (a) Reef and continent builders.
    - (b) Coral deposits now limestone beds.
    - (c) Precious coral.
- d. Echinoderms.
  - (1) Starfish harmful to oysters.
  - (2) Sea-cucumbers eaten by Chinese, etc.
- e. Worms.
  - (1) Earthworms necessary in cultivated soil.
  - (2) Parasitic worms cause disease in man and animals.
- f. Molluscs.
  - (1) Raw food, also cooked (clams, oysters, etc.).
  - (2) Shells furnish mother-of-pearl, buttons, chicken feed.
  - (3) Precious pearls (Persia and Ceylon).
  - (4) Shells for money and ornament.
  - (5) Squids for bait, cuttle bone, and sepia.
- g. Crustacea.
  - (1) Lobster, crab, shrimp, etc., for food.
  - (2) Small forms for fish food.
  - (3) Barnacles harmful.

h. Arachnida.
   (1) Spiders useful in killing flies, etc.
   (2) Scorpions dangerous, but not fatal.
   (3) Daddy-long-legs feed on plant lice.
   (4) Mites and ticks parasitic and harmful to man and animals.

i. Insects.
   (1) Harmful activities.
      (a) Destroy crops.
      (b) Transmit disease.
      (c) Injure domestic animals.
      (d) Destroy clothing and buildings.
      (e) Annoy and injure man.
   (2) Useful activities.
      (a) Pollination.
      (b) Scavengers.
      (c) Kill injurious insects.
      (d) Silk.
      (e) Furnish honey and wax.
      (f) Dyes.
      (g) Shellac.
      (h) Ink material.

CHAPTER L

THE ECONOMIC BIOLOGY OF VERTEBRATES

Vocabulary

Isinglass, a kind of gelatine, *not* the substance in coal stove windows, which is mica.
Appropriate (used as a verb) to take away for use.
Appropriate (used as an adjective) suitable.

Fishes. The chief value of fish is as food, both for other animals and for man. Out of 12,000 known species, at least 5000 are valuable as human food.

The annual catch of salmon, cod, halibut, mackerel, and herring amounts to many millions of dollars, while the shad, smelt, perch, and bass are almost as valuable. The Pacific salmon alone are worth about $15,000,000 per year and the Atlantic cod returns about $20,000,000. In fact it was the cod returns in fisheries that induced the settlement of New England, and pictures of this celebrated fish may yet be seen in the statehouse of Massachusetts, on the bank notes of Nova Scotia and the postage stamps of Newfoundland. The fish crop of Alaska in 1915 amounted to three times the purchase cost of the whole territory.

Fish are eaten fresh, smoked, salted, dried, pickled, and canned. Despite these various ways of preparation we do not use them as extensively as we should.

The Government maintains departments of fisheries in thirty-two states which regulate the times and methods of catching, provides hatcheries for artificial raising of valuable kinds, and distributes young fish to stock ponds and rivers so that the supply may not become exhausted.

Another important use for fish is as fertilizer since they are rich in phosphorous compounds which most plants need. The menhaden is much used for this purpose as well as for its oil.

In 1913 over a billion of this species were taken, from which were made 6,500,000 gallons of oil and 90,000 tons of fertilizer. The total weight of the year's catch of this one kind was more than the weight of all the inhabitants of Greater New York.

Cod-liver oil is the easiest oxidized fat food in the world and is valuable as a medicine. Isinglass, a fine quality of gelatine, is obtained from the air bladders of certain fishes. Glue is another important product made from waste parts and bones of all sorts of fish.

Amphibia. The chief value of this group lies in its activities in destroying harmful insects. Frogs, toads, and salamanders all unite in feeding upon them, the toad being especially useful in this respect. To a very much less extent, frog legs are used for food; frogs might much better be left to fight insects, rather than be used for this purpose.

Reptiles. We usually consider this group as useless or even harmful, but with the rare exceptions of the venomous snakes, the Gila monster, and a few man-eating crocodiles, this is not true. Most snakes destroy either insects or harmful rodents, though a few eat frogs, birds, or eggs.

The turtle family not only destroys insects, but sea turtles furnish flesh and eggs as foods and tortoise shell for ornaments. Alligators and crocodiles are not particularly valuable and occasionally are dangerous. Their hides are sometimes made into leather.

Birds. The economic value of birds has already been mentioned; they are our chief ally in the fight against our insect enemies; they provide flesh and eggs for food; they supply feathers for bedding and ornament; while their bright colors and sweet songs have always made them cheerful companions and pets for man.

In order to preserve these valuable members of society we can

1. Learn to observe the laws made for their protection.

2. Help restrain their enemies, the plume hunters, game hogs, cats, red squirrels, black snakes, and certain birds such as Cooper's hawk, sharp-shinned hawk, great horned owl, and English sparrow.

3. Help preserve the forests and city trees for their nesting.
4. Provide winter food for city birds.
5. Provide nesting boxes for some city species.
6. Try to inform others along these lines.

From Brown.

FIG. 186. The wild jungle fowl of India, probable ancestor of domestic fowls.

Mammals. *Food.* This group includes the animals that we usually think of as of the most importance to man. The ungulates furnish his chief sources of animal food, since here belong cattle, sheep, and pigs, and many others. Man uses as flesh food practically all hoofed animals with four toes, and from cattle also obtains milk, butter, and cheese. Besides these, rabbits, squirrels, bears, raccoons, opossums, seals, and even bats, monkeys, and whales are important foods for man. In fact all mammals except the cat and dog families are used as food by some group of people.

Clothing. Next to their value as food, the mammal's chief products are their body coverings, which man appropriates. Sheep, goats, camels, and llamas all produce valuable wools.

The list of fur-bearing animals includes the otter, mink, ermine, marten, and their relatives, together with foxes, wolves, bears, tiger, leopard, and even the humble skunk, while the sea otter and seal are much more valuable. The seal herd belonging to the United States is the most valuable government

possession in the world. Leather is obtained from the hides of cattle, sheep, horse, hog, goat, seal, walrus, buffalo and many other mammals and is absolutely indispensable because it has no satisfactory artificial substitute.

Various Products. The whale, largest of mammals, provides several curious products; oil and a fine wax (spermaceti) are obtained from some kinds. The oil whale also produces "whale bone" which is made from a fibrous strainer device developed from the roof of the mouth. Ambergris is an abnormal secretion of the liver of sperm whales which is of enormous value as a perfume.

Horn and bone products of many mammals are used for making ornaments, buttons, handles, etc. Ivory comes from the tusks (teeth) of the elephant and walrus.

Transportation. Of much greater importance than these last items is the use of many mammals as beasts of burden. The horse is easily first, with oxen, camels, dogs, goats, llamas, reindeer, water buffaloes, and elephants used in different countries to a greater or less extent.

Pets. Mammals have been used by many as companions and pets; in this class the dog is first, the horse, cat, and occasionally other forms being admitted to this select society.

Among the mammals, also, are most of the "domestic" animals which man has learned to tame and breed for many of the uses just mentioned. Here again, the dog comes first, as it was probably derived from a domesticated wolf which primitive man tamed for his company, protection, and aid in the hunt. Probably cattle or sheep were next controlled by man, though the horse may have preceded them in learning to carry his master in battle or the chase. To this list man is still adding useful species either by breeding from present forms, or by taming new ones when their value is discovered.

The other side of the account is represented by a few harmful mammals, dangerous either to man himself, to his domestic animals, or to his crops. Among these are the large carnivora, such as the tiger, lion, wolf, etc., which attack man or his flocks. In this country carnivora destroy about $15,000,000 worth of stock

per year. The rodents, especially rats, mice, and squirrels do enormous harm by destroying grains and other food stuffs. In the case of the rat alone, the wastage amounts to about $200,000,000 annually. Furthermore, rats and some squirrels are infested with fleas which transmit the plague to man, and thus are even more seriously harmful. Rats have been called "the worst mammalian pest" and seem to deserve the title. It will be seen that the mammals as a whole are not only extremely useful, but absolutely essential to man; without them our present civilization and mode of life would be impossible.

COLLATERAL READING

The following books have many references in various places, see index: *Familiar Fish*, McCarthy; *American Food and Game Fishes*, Jordan and Everman; *American Animals*, Stone and Cram; *American Natural History*, Hornaday; *Our Vanishing Wild Life*, Hornaday; *N. Y. Forest, Fish, and Game Commission Reports; The Frog Book*, Ditmars; *The Reptile Book*, Ditmars; *Economic Zoölogy*, Osborn, from page 311 to end; *Useful Birds*, Forbush; *Economic Value of Birds to the State*, Chapman, N. Y. F. F. and G. Com.; *Birds of Eastern North America*, Chapman, pp. 6–7; *Bird Life*, Chapman, Chap. I, and note; *Birds of Eastern North America* Reed, pp. 12–14; *National Geographic Magazine*, November, 1916, and May, 1918; *Domesticated Plants and Animals*, Davenport; *Birds in their Relation to Man*, Weed and Dearborn.

SUMMARY OF CHAPTER L

THE ECONOMIC BIOLOGY OF VERTEBRATES

1. Fishes.
- a. Food for man (5000 species).
- b. Food for aquatic animals.
- c. Fertilizer.
- d. Oil.
- e. Glue, isinglass.

2. Amphibia.
- a. Destroyers of insects.
- b. Food (frog legs).

3. Reptiles.
- a. Harmful activities.
  - (1) Venomous snakes (rattler and copperhead).
  - (2) Venomous lizard (Gila monster).
  - (3) Man-eating crocodiles.
  - (4) Destroy birds' eggs and young (black snake).
  - (5) Destroy frogs (black and garter snakes).

b. Useful activities.
   (1) Destroy insects.
   (2) Destroy harmful rodents.
   (3) Furnish food (turtle meat and eggs).
   (4) Furnish shell (tortoise).
   (5) Furnish leather (alligator).

4. Birds.

a. Value.
   (1) Destroy insects.
   (2) Destroy weed seeds.
   (3) Food (flesh and eggs).
   (4) Feathers.
   (5) Companions.

b. How to protect birds.
   (1) Obey and enforce protective laws.
   (2) Restrain their enemies.
      (a) Plume hunters and game hogs.
      (b) Cats, red squirrels, snakes.
      (c) Cooper's hawk, sharp-shinned hawk, horned owl, English sparrow.
   (3) Preserve forests and trees.
   (4) Provide winter food and summer homes.

5. Mammals.

a. Food.
   (1) Meat and milk (ungulates).
   (2) Meat (various forms except dog and cat groups).

b. Clothing.
   (1) Wool (sheep, goat, camel, llama).
   (2) Fur (rodents and carnivora).
   (3) Leather (ungulates, etc.).

c. Various products.
   (1) From whale.
      (a) Oil.
      (b) Wax.
      (c) "Whalebone."
      (d) Ambergris.
   (2) From elephant.
      (a) Ivory.
   (3) From various mammals.
      (a) Horn.
      (b) Bone.

d. Transportation.
   (1) Horses.
   (2) Oxen.
   (3) Camels.
   (4) Reindeer.
   (5) Dogs.
   (6) Goats.
   (7) Llamas.
   (8) Water buffalo.

e. Pets.
   (1) Dog, horse, cat, etc.
   (2) "Domestic animals."

f. Harmful mammals.
   (1) Large carnivora (lion, tiger, wolf).
   (2) Rodents (rats, mice, squirrels).
      (a) Waste food stuffs.
      (b) Transmit disease.

CHAPTER LI

BIOLOGY AND AGRICULTURE

Vocabulary

Pulverizing, making into powder.
Tillage, plowing, cultivating, harrowing, or hoeing the soil.
Retain, to hold.
Diminishing, making smaller.

Civilization rests upon the soil. In so far as our knowledge enables us to use the soil to best advantage, only so far can we advance in population, wealth, and national growth. At present we are far from realizing our greatest agricultural efficiency, as the following tabulations show:

China	supports	3500	people	per	square	mile.
Japan	"	2000	"	"	"	"
Belgium	"	300	"	"	"	"
United States	"	30	"	"	"	"

As to crop yields we compare as follows.

	Maximum yield per acre	*U. S. yield per acre*
Potatoes	500 bushels	96 bushels
Wheat	50 "	14 "
Corn	100 "	28 "
Oats	100 "	32 "

Evidently there is much to be learned before we shall obtain the best results from our national resources.

Soil Formation. Soil is formed from rock by the action of heat and cold, water and ice, bacteria and protozoa, which are all engaged in pulverizing its particles and adding to it organic matter and nitrogen compounds. Proper tillage admits air for plant use and carbon dioxide to act chemically on the soil; it loosens the soil grains to permit easy root growth and exposes new stores of plant food for them to absorb. Loosening the top

layers by frequent tillage also forms a protective layer which retains water.

Dry Farming. In dry regions the surface of the soil is pulverized after each rain and thus the earth retains what little water has fallen. A three-inch layer, kept loose and fine, will retain a great deal of water. There is a saying that "a rake is as good as a watering pot."

In some of our western states this method of retaining water is kept up for the whole season, crops being planted in the

Courtesy of U. S. Dept. of Agriculture.

FIG. 187. Harvesting grain.

alternate years. In this way the soil accumulates enough moisture in one season to supply the crop for the next. Such a plan is sometimes called "dry farming."

In other parts of the country, irrigation has been employed to provide sufficient water. Dams are built by the government, canals and ditches distribute the water, and land that would be desert, literally "blossoms like the rose." The soil is often rich, so far as its composition is concerned, but, lacking the water, crops could not be raised.

A certain amount of organic matter from plant refuse, stable manure, and leaves must be present in the soil. Such material forms what is called *humus* and helps in keeping the soil loose,

retaining water, and furnishing plant foods. Without it the soil tends to pack, which allows escape of water and decreases the air supply.

Soil Composition. Plants can obtain oxygen, hydrogen, and carbon from air and water, but must depend on the soil for all compounds of nitrogen, phosphorus, and potassium which are just as essential in the making of protoplasm.

To be fertile, a soil must contain compounds of these elements in soluble form, available for plant use. The average soil contains a supply of potassium compounds sufficient for 2000 years, phosphorous compounds to last for 130 years, but nitrogen compounds only sufficient for 70 years' use. Yet nitrogen compounds are more essential and used in greater quantity than either of the others.

Evidently the supply of nitrogen is the limiting factor in determining how long a soil will remain productive; hence its return to the soil is one of the greatest problems in agriculture.

Maintaining the Soil. Every crop removes these essential elements from the soil, and erosion may rob it of as much more, so man has learned to replace the removed substances by 1. fertilizers, 2. nitrifying bacteria, 3. crop rotation.

1. *Fertilizers* obtain potash as potassium chloride and sulphate, largely from German deposits. Phosphorous compounds are obtained from bone ash and the phosphate rock found in California and Florida. Nitrogen is supplied to the soil by

a. Natural manures.
b. Nitrate of soda from Chile.
c. Slaughter house wastes.
d. Ammonia compounds from coal distillation.
e. Action of nitrifying bacteria.

A complete fertilizer should supply all three elements, but as the soil often has enough of one or two, this is sometimes unnecessary and analysis of the soil is the only sure way of determining its needs.

2. *Bacteria,* found in nodules on the roots of clover, peas, alfalfa, and lentils have the power of converting the free nitrogen of the air into nitrogen compounds, available for plant

use, so clover crops actually benefit the land so far as nitrogen is concerned. Soils lacking these bacteria are sometimes inoculated with pure cultures of the desired kinds. This not only benefits the clover or pea crops but adds nitrogen compounds for plants that may follow them.

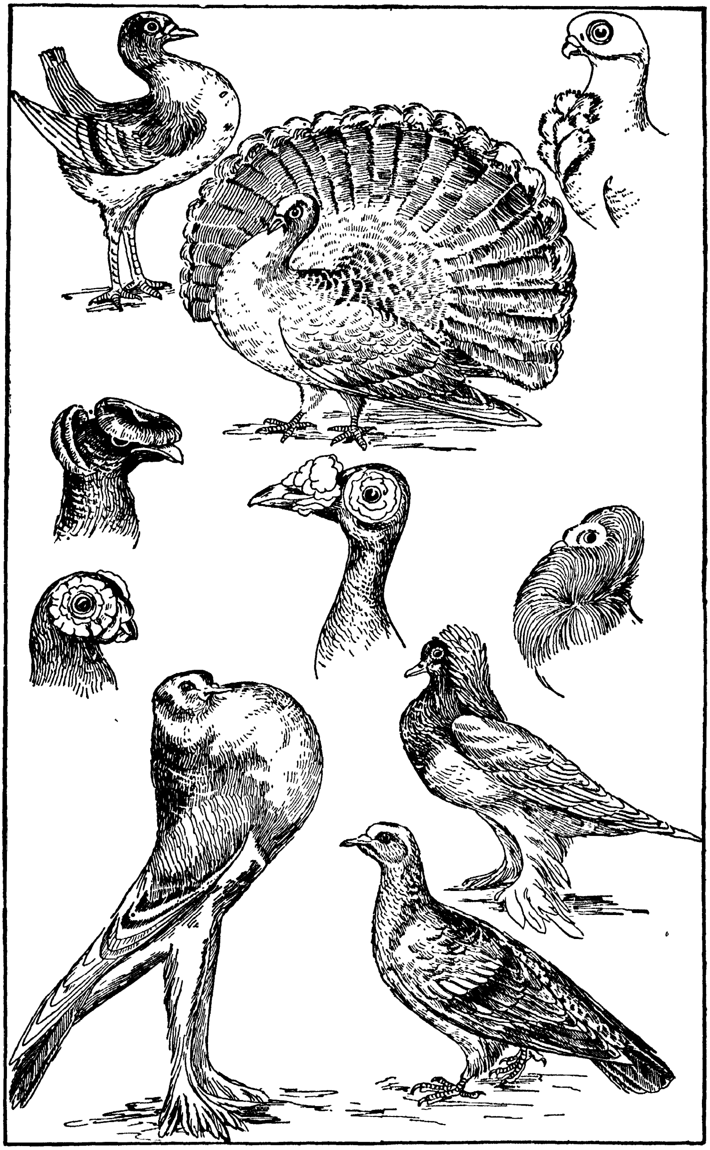
Other bacteria help in decay of organic matter and return it to the soil in useful forms; all dead tissue and natural manures are acted upon in this way. Bacterial and chemical processes in the soil are constantly transforming organic into inorganic compounds, making them into simpler substances such as can be used by plants again.

3. *Rotation of crops* merely applies what has just been said. The farmer cannot use the same field for the same crop, year after year, without removing the special soil compounds which that crop requires and thus diminishing his return. He therefore varies his crop so that clover or peas shall have a chance to replace nitrogen compounds which wheat or corn may have removed. He also alternates between crops that require hoeing and those that do not, so that the soil may benefit by the different methods of cultivation. Often the clover crop is plowed under so that the organic matter as well as the nitrogen is returned to the soil.

Plant Breeding. Not only does biology bear upon soil conditions but also upon all that relates to seed planting, germination, and growth. Especially is this true in the matter of testing and selection of seed and in crossing and breeding of new varieties. A glance at any seed catalog will show the great advances that are being made by applying biologic methods to bettering the varieties of plants.

In this same connection, all other methods of plant propagation are concerned. Cuttings and grafts, pollination, transplanting, and pruning all involve the use of biological information.

In 1900 the British Millers' Association decided that the wheat that was then raised in England was so unsatisfactory that they engaged Prof. R. H. Biffen of Cambridge University to try to improve the quality.



From Haeckel.

FIG. 188. Various races of pigeons, all probably descended from the European rock dove, *Columba livia*, shown in lower right hand corner.

Professor Biffen obtained seed of all the different wheats which had any one desirable characteristic, such as stout straw full heads, immunity to rust, or resistance to cold weather These he raised separately, and cross-pollinated by hand combining their desirable features, till after years of effort selection, crossing, and rejection of the unfit, he developed the present English wheat which combines nearly all the characteristics which the millers demanded.

In the United States, Mr. Burbank stands at the head of our "practical" plant breeders. By cross-breeding and rigid selection he has developed many valuable new species. His improved potato adds $17,500,000 to the annual income of the farmers of the United States. He has increased the yield of some kinds of corn twenty fold. He has improved known fruits in their quality, hardiness, or resistance to insects. He has developed several new fruits, either from wild species or by crossing. Many large and beautiful flowers have been produced, such as the mammoth poppy with a diameter of ten inches, and the delicate shasta daisy. One of his most notable successes has been the spineless cactus, which is now available as cattle fodder in regions where it is difficult to provide food for stock.

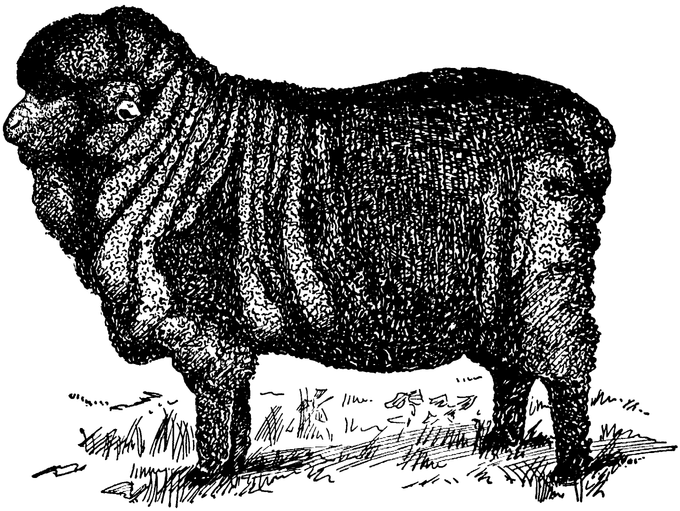
Burbank's work is merely an example of the application of biologic laws to plant improvement, such as is being carried on by all seedsmen and all intelligent farmers and gardeners When we save seed from our best or earliest plants, keep them separate from less satisfactory kinds, and plant their seed again, we are following in the footsteps of these great breeders and utilizing the same laws of inheritance.

By similar methods, practically every plant that man cultivates has been improved and developed into forms that better serve his purposes.

Plant Protection. Biology comes to the aid of the farmer in his struggle against plant disease. Molds, rusts, blights, and bacterial attacks all have to be met by proper treatment of seed with formalin, or the plant itself with fungus-killing sprays like Bordeaux mixture.

Insect enemies and the means of checking them open another chapter of farm biology. Here also belongs the study of useful birds and their enormous value as insect destroyers.

Animal Husbandry. Principles of biology are also applied to animal raising, their care and feeding, selection and domestication. Especially is this true in the case of animal breeding for improved varieties. Here are involved selection, inheritance, and cross-breeding.



From Shaw.

FIG. 189. Typical American Merino ewe, a highly specialized breed of sheep, with fine, close-set wool.

By following well-known biologic methods man can select almost any group of desirable characteristics and produce a breed possessing them. As evidence of this, note the numerous and widely different types of horse, cow, or dog that man has thus developed.

In early years England had three general types of sheep,—some hornless, some with fine wool, and some producing good mutton. By long and careful breeding and by rejecting all unsatisfactory animals for propagation, they now have several races that combine in a large degree all these useful features.

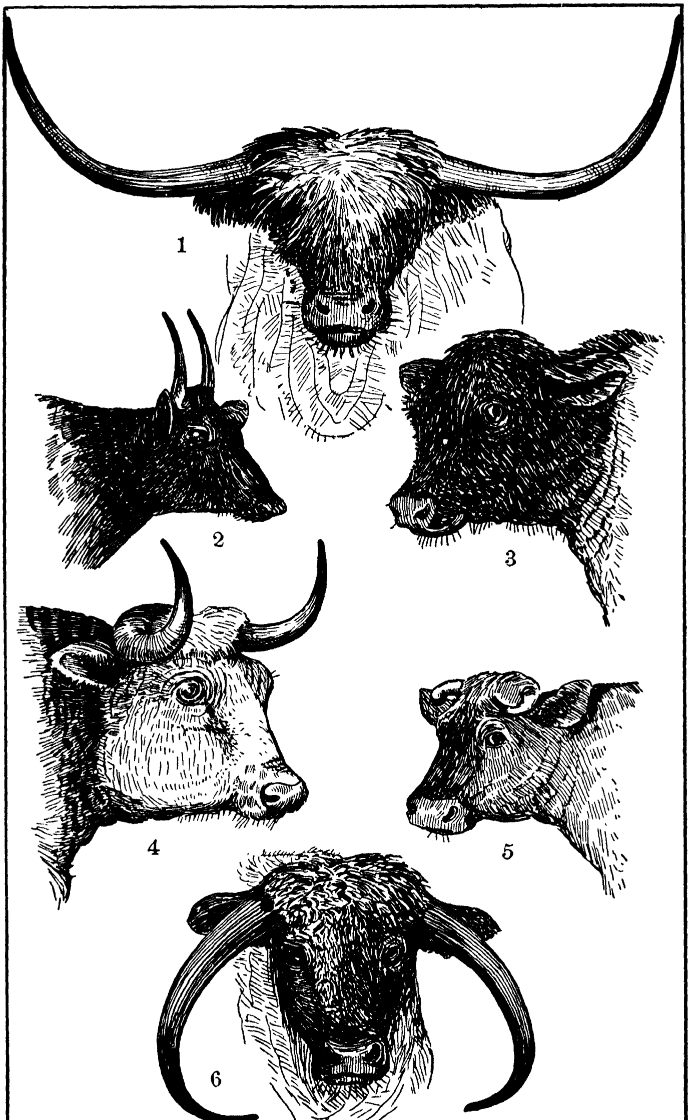


FIG. 190. Heads of various British breeds of domestic cattle, showing variations in shape of head and condition of horns: 1, Highland Scot; 2, Irish Kerry; 3, Aberdeen Angus; 4, Hereford; 5, Jersey; 6, Long-horned Midland.

In similar ways we have different breeds of cows for different purposes, the Jersey producing as much butter fat as ten ordinary cows, the Holstein for large milk production, and the Hereford for beef.

Horses for trotting, running, draught, or mere appearance, are bred and selected and their pedigrees so carefully recorded that many a trotter can trace his ancestry much further back than most human aristocrats. The advantage lies with the horse in another way, since his ancestors were valued because they could *do* something well, and not merely because of the accident of birth.

Bacteria on the Farm. Care of milk on the farm has been already mentioned, but in cream, butter, and cheese as well the farmer is using some bacteria and opposing others. The characteristic flavors and odors of butter and cheese are partly due to useful bacterial action, while the spoiling and decay of these products is due to attack of others.

Bacteria are working also in the preparation of ensilage and the "curing" of meats and tobacco. In fact if you will look back over your work you may be surprised at the extensive rôle of bacteria as farm laborers.

Here are some of their activities, good and bad:

They aid in decay of organic matter for fertilizers.
They cause decay of valuable food stuffs.
They help return nitrogen to the soil.
They cause many plant and animal diseases.
They aid in all dairy processes.
They spread disease by way of milk and other foods.
They help in producing ensilage.
They aid in curing meats, flax, and tobacco.

There is no branch of industry so important, and none so closely associated with biology as the industry of agriculture. Most of the material found in the chapters on economic biology both of plants and animals, together with much under forestry and general conservation methods, bears directly on this fundamental occupation.

COLLATERAL READING

Agriculture for Beginners, Burkett, Stevens and Hill; *The Fertility of the Land,* Roberts; *Soil Fertility and Permanent Agriculture,* Hopkins; *Principles of Agriculture,* Bailey; *Farmers for Forty Centuries,* King; *Fertilizers,* Voorhees; *Practical Agriculture,* Wilkinson; *First Book of Farming,* Goodrich; *Cyclopedia of American Agriculture,* Vols. II and III; *Milk and its Products,* Wing; *Types and Breeds of Farm Animals,* Plumb; *Commerce and Industry,* Smith, pp. 20–85; *Principles of Breeding,* Davenport; *Domesticated Animals,* Shaler; *First Principles of Agriculture,* Goff and Mayne; *Science of Plant Life,* Transeau, pp. 217–232.

Plant Breeding

Elementary Studies in Botany, Coulter, pp. 326–339; *New Creations in Plant Life,* Harwood, entire; *Origin of Cultivated Plants,* De Candolle, entire; *Experiments in Plants,* Osterhout, pp. 409–453; *Botany for Schools,* Atkinson, pp. 455–478; *The Living Plant,* Ganong, pp. 426–444; *Species and Varieties* (Mutation), De Vries, entire; *Domesticated Animals and Plants,* Davenport, entire.

Domestic Animals

Elementary Zoölogy, Davenport, pp. 420–450; *Domesticated Animals and Plants,* Davenport, entire; *Economic Zoölogy,* Kellogg and Doane, pp. 321–334; *Pet Book,* Comstock, entire; *Farm Bulletins.*

SUMMARY OF CHAPTER LI

BIOLOGY AND AGRICULTURE

1. Importance of agriculture.

2. Lack of efficient development.

3. Soil formation.

4. Soil composition.
- a. Potassium compounds.
- b. Phosphorus compounds.
- c. Nitrogen compounds.
- d. Organic matter (humus).

5. Soil maintenance.
- a. By fertilizers.
- b. By bacterial action.
- c. By crop rotation and cultivation.
- d. Dry farming.

6. Plant breeding.

7. Plant protection.
- a. From insect enemies.
- b. From fungus attack.

8. Animal husbandry.
- a. Care and feeding of stock.
- b. Breeding new forms.

9. Bacteria on the farm.

CHAPTER LII

THE ECONOMIC IMPORTANCE OF FORESTS

Vocabulary

Erosion, washing away of soil.
Retention, holding.
Re-forestation, scientific replacement of trees when cut.

The great importance of forests is little appreciated. When we are told that they occupy 35 per cent of the area of the United States and that lumbering is our second largest industry, still their most important services are overlooked.

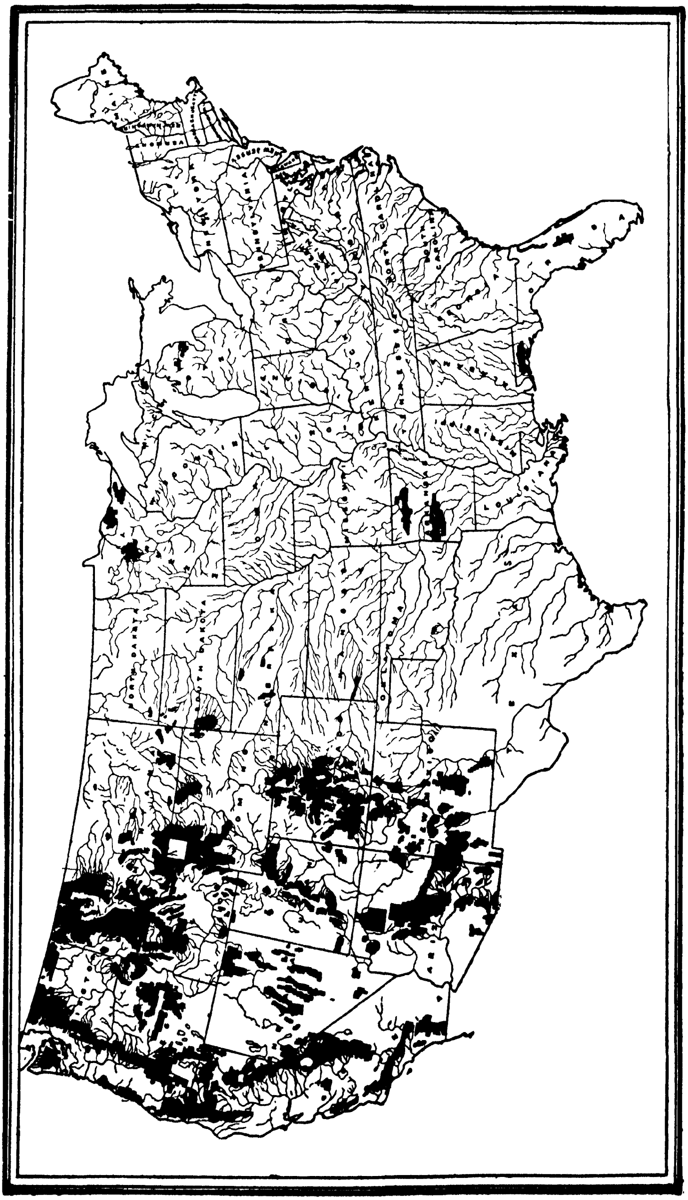
Value of Forests

Control of Water Supply. The most important service rendered by forests is in regulating water supply. The forest area acts like an enormous sponge absorbing the heavy rainfall in its layer of humus. The foliage prevents the rain from falling directly upon the soil which therefore is not washed away. The network of roots accomplishes the same result and the deep layer of humus on the forest floor retains the water and allows a gradual "run off."

This secures the following important results:

1. Prevents floods and causes steady stream flow.
2. Prevents drought by storing water in the wet season.
3. Prevents washing of soil into rivers.
4. Keeps rivers at uniform level for transport.

The effect of forests in this regard can only be appreciated when compared with an area which has no forest protection and is subject to heavy rainfall, such as the Bad Lands of Dakota. Here the water runs off at once in floods, while between rains, the land is almost a desert, due to drought, and the rivers are so filled with mud and so changeable in levels as to be useless for commerce or power.



From Smith's "Commerce and Industry."

FIG. 191. Map showing distribution of the National Forests (1910). This total area is greater than that of England, Ireland, Scotland, and Wales.

Benefit to Soil. The early settlers regarded the forests as the enemy to agriculture, and so they were, insomuch as some clearings had to be made to make room for the farms, but in a larger sense, the forests are a distinct benefit to the soil. Erosion, the washing away of soil by rain, is one of the worst enemies of agriculture and this is prevented by the forest areas, whose roots hold back the earth and whose leaves protect the surface. Furthermore, the organic matter (humus) which collects on the forest floor supplies an essential element to all fertile soils.

In some areas, the forests perform another function in preventing the spread of wind-blown sand over fertile areas which are thus saved for use.

Effect of Forests on Climate. While this may not rank with the two preceding in importance, yet it is certain that by their retention of moisture, forests do modify the climate over large areas and apparently influence local rain-fall as well. To a less extent, forests affect climate by their action as a protection from wind or sun.

Forests as Home for Birds and Game. This is a matter often overlooked, but, when we recall the enormous economic value of birds and realize that they depend largely on the forests for their home, the importance of this factor is apparent. As a home for fur-bearing animals, game, and fish the forests also are important to man in many relations little realized.

Forest Products. When the economic value of forests is mentioned, one naturally thinks of the lumber and other direct products as the most important. While no more important than some already mentioned, the variety and value of the manufactured forest products is enormous.

Time will not permit discussing each in detail so, in the tabulation which follows, some of the most important items are mentioned.

FOREST PRODUCTS

1. **Timber products.** Lumber, shingles, railroad ties, ship and mine timbers, poles, etc.
   (*a*) U. S. produces 38,000,000 thousand feet of "soft wood" lumber per year, and 8,000,000 thousand feet of hard wood lumber.

(*b*) The chief kinds are
yellow pine from Carolina, Georgia, etc. (40%).
white pine from Michigan, Wisconsin, Minnesota.
spruce and redwood from the Pacific slope.

(*c*) The enormous number of trees cut may be judged when we realize that 40% is wasted in making lumber.

(*d*) Railroads use 2500 ties per mile—there are about 200,000 miles in U. S. and the ties have to be replaced every seven years; this means the use of about 70,000,000 ties per year.

2. **Paper.** A single New York daily newspaper uses for paper the spruce trees from 44 acres per day.
The greatest amount of paper is made in New York, Wisconsin, and New England.

3. **Fuel.** Coal is indirectly a forest product as it is the carbon from trees of ages ago, partly decomposed under the earth by heat and pressure. Wood and charcoal also important.

4. **Naval stores.** These are so called because tar and pitch are used in connection with ship building and cordage. The crude pitch is obtained by notching the southern pines and collecting the product which is distilled, making tar, turpentine, and rosin. U. S. exports seven times as much turpentine and ten times as much rosin as any other country. The value reaches $36,000,000 per year.

5. **Tanning materials.** Hemlock, chestnut, quebracho and other tropical woods.

6. **Maple sugar.** U. S. produces 50,000,000 pounds and 4,000,000 gallons of syrup per year, of which Vermont and New York supply over three-quarters.

7. **Spruce gum.** This gum forms in masses on the bark of spruces and is gathered and cleaned in the winter. Really fine gum is worth several dollars a pound.

8. **Distillation products.** Various kinds of hard wood are heated in closed iron cylinders, destructive distillation goes on, charcoal remains in the cylinders and the other products go off as vapors and are condensed and separated. We will learn more about this in chemistry. For the present notice how many products there are and for what various and important purposes they are used.

Distillation products	*Uses*
charcoal	fuel
lamp black	ink
tar	tar paper, wagon grease, and wood preservation
oil	varnish, soap, disinfectants, ink
oxalic acid	dyeing, bleaching, making formic acid
acetic acid	white lead paint, dyes, and medicines
wood alcohol	varnish, solvent, dyes, denaturing alcohol, fuel, making formaldehyde, and smokeless powder
acetone	explosives, films, dyes, and solvent

Forest Enemies

Man. Valuable as they are, forests have many enemies, and strange as it may seem, one of the worst of them is man. Of course we destroy much standing timber for necessary use and for clearing for agriculture, but much more is utterly wasted in other ways. Annual growth in the United States is 7,000,000,000 feet but the annual consumption totals over 20,000,000,000 feet.

Careless lumbering, in which only a few trees are used and many destroyed, or wasteful methods, by which only one-fourth of the cut timber ever becomes lumber, are some of man's methods of attack. Cutting hemlock and using only the tan bark, leaving the stripped timber a total loss and danger in case of fire, is another barbarous waste for which man is responsible.

Fire is one of the forests' worst foes and except for lightning, man is the author of them all. Sparks from locomotives and camp fires of careless hunters account for some which start accidentally, while grazers and berry pickers start fires on purpose to help their crops, and men, clearing land, often lose control of their fires and cause great destruction. In 1915 there were 40,000 fires, covering 6,000,000 acres, or over 1 per cent of all forests in United States, which caused a loss of $7,000,000 and many lives. During the same year 2½ million dollars were spent for forest protection or only one-third the year's loss.

Insect Enemies. In our study of insects, the damage which they do to crops was mentioned, and the forest crops are no exception. The sawfly, bark beetles, gypsy moth, tent caterpillar, and tussock moth are some of the most harmful, and, unlike the orchard pests, the extent of the forests makes spraying impossible. The birds are almost our sole protection against these forest enemies, though toads, snakes, and ichneumon flies do their share.

Fungus Enemies. Whenever we see a shelf fungus on a tree we may be sure that tree is doomed unless help is provided. But the most damage is done by less conspicuous forms, such as the rusts and blights, of which the chestnut blight is a notable ex-

ample. (Not only are the trees destroyed but their lumber is ruined by fungi, both in standing timber and often after it is cut and piled.)

Weather Conditions. Despite their great strength, trees often fall victims to wind and snow, and in many regions great strips are blown down by tornadoes making the almost impassable "windfalls" which later, when dead and dry, furnish ideal fuel for forest fires. Sleet storms destroy many buds and even large branches, especially if followed by severe winds, and thus damage or kill many valuable forest trees.

Grazing Animals and Others. Large herds of cattle or sheep often damage forests by trampling on the young trees and by feeding on the limbs and leaves. Mice, porcupines, and rabbits often girdle the trees by eating their bark, and some little damage is done by birds and squirrels which eat their seeds.

Forest Protection

The value of the forests of the United States is evidently very great, but only recently have efficient means been taken to protect them.

Legal Protection. To begin with, one of the most important means of protection lies in the hearty coöperation of every citizen in observing and enforcing the present forest laws as to fire prevention and proper lumbering.

Careful Lumbering. The average lumberman harvests his crop, but does not plant another. Hence we face the ever-rising cost of lumber, whereas if the timber annually cut is regulated so as not to exceed the year's growth the forest will continue to produce like any other crop.

Re-forestation. Another means of protection consists in re-planting, either by setting out small trees, or cutting only mature ones and leaving young and seed-bearing trees so that nature can attend to the re-planting.

Forest Reserves. The Government has established large forest reserves which are kept by the nation to protect drainage for irrigation, to supply grazing areas, and provide timber under supervised cutting.

Forest Rangers. To protect these enormous tracts of Government forest from fire or theft, there is provided a body of expert Forest Rangers under Government control.

These men patrol the forests, report and prosecute theft, and organize to fight forest fires before they get out of control. This work has saved millions of dollars and many lives in the line of fire prevention alone.

Forestry Schools. Furthermore, there are established Forestry Schools at Cornell, Michigan, Syracuse, Yale, and elsewhere, in which the scientific methods of lumbering, planting, and protection are taught. For those unable to attend these institutions, many bulletins and other publications are available from state and national governments, giving valuable information regarding this important source of our natural wealth.

The farmer who would cut down his apple trees to gather the fruit, or who harvested a crop without planting another, would be considered insane, yet the treatment of our forest resources amounts almost to this. The sooner we realize the fact that a forest is a crop to be tended and gathered, planted, and protected like any other, the sooner our lumber, paper, and other products will cease to increase in cost.

Timber Structure

A great deal of the value of lumber depends on one of three factors, its durability, strength, or appearance. These in turn depend upon the minute structure of the tree stem and though this was discussed in Chapter XI, it needs to be recalled in this connection.

A woody stem is made up of wood fibres and ducts (tracheids in the evergreens). These are arranged in annual rings caused by larger ducts forming in the spring, and fewer and smaller ones in autumn and winter.

"Grain." Evidently a board cut from such a stem will have alternate layers of harder and softer tissue which cause the "grain" seen in most woods. If the board is cut from near the side of a log, few annual rings will show on the surface, their *sides* will be exposed for wear and will give a grain figure like

(A). If the board be cut near the centre of the log (B) *all* the annual rings will show and their *edges* are exposed for wear which makes the lumber more durable and less liable to sliver up. The former (A) is known as "bastard sawed" and the latter (B) as "rift sawed" lumber. As a log is cut up, the first boards will be bastard grain, then as the center is approached, more and more nearly rift grain, and finally bastard cut after the centre is passed. Obviously there are more bastard than rift boards and hence the latter are more expensive, as well as more durable.

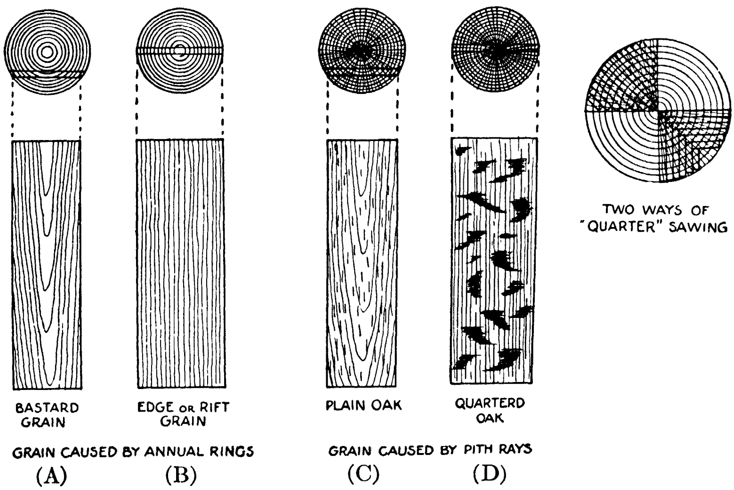


FIG. 192. Diagram showing cause of grain in timber and the various ways of sawing so as to take advantage of the grain.

Quarter Grain. In all stems there are pith rays extending from pith to bark, but only in oak, maple, sycamore, and a few others are they large enough to affect the grain of the timber. Since these pith rays run toward the bark, a board cut at (C) would show only their cut ends which would be too small to notice, whereas, if the board be cut at (D) the pith rays will be cut more or less sidewise and will show as the plates or flakes which are characteristic of "quartered oak," giving it its beauty and value.

In order to get as many boards as possible showing this flake

grain (side of pith ray), the logs are sometimes cut in quarters and then sawed from the centre outwards so as to show the sides of as many pith rays as possible—hence the term "quarter sawed" or "quartered oak." The bastard cut oak, which shows only the annual ring grain (as in A) is sold as "plain" oak and while almost as durable is not nearly as handsome.

Heart and Sap-wood. As a tree grows larger, only the outer annual rings carry sap in their ducts, while the inner region becomes practically dead, its only function being support. This centre part is called the "heart wood" and is often darker in color and more durable than the outer, live region or "sap-wood." The heart of a tree may totally decay and yet cause the tree no harm other than reducing its strength, but the sap-wood is necessary to the growth of the tree and may even keep it alive when the bark has been girdled.

Shrinkage and Warping. Fresh-cut timber contains much water and the process of drying, called "seasoning," has to be thoroughly accomplished before it can be used. This is because lumber shrinks as it dries and no amount of nailing will hold poorly seasoned boards together. As a board dries there is a tendency for the side nearest the bark to shrink fastest causing the board to curve away from the centre, or "warp." Unless the lumber be properly piled and dried it may be rendered unfit for use.

Hard and Soft Woods. Trees can be grouped in two classes, those with broad leaves, which are shed annually (maple, oak) and those with needle-shaped leaves, which are not all shed at one time (pine, spruce). The former produce "hard wood" lumber and the latter "soft wood," though some broad-leaved trees have lumber that is very soft (basswood, willow) and some pines produce "hard pine" lumber, which nevertheless, is classed as a "soft wood."

"Knots" in lumber are places where a branch has been broken off and the scar covered by additional annual rings. If the wound healed at once and no rot commenced, the knot is tight and does not harm the lumber so much, but if the healing was incomplete, a loose knot results and a knot-hole in the board is the result.

A tree grows in height only at the tips of new branches; it grows in thickness layer by layer, over all parts, hence a nail driven into a tree will always remain at the same height from the ground, but will be covered, in time, by the growth in thickness.

Street Trees. In proportion to their number, trees are more valuable in the city than in the forest. Shade trees add to the cash value of property in the same way as do wide streets, good pavements, and favorable location. A city always is proud of handsome trees and shady streets, but often there is little care exercised in their planting or maintenance. If quick growth and immediate results are wanted, soft maples or poplars are used, but these are short lived and poplars are not very desirable. Elms, red oaks, and hard maples, on the other hand, grow slowly, but are sturdy and live to great age.

City trees require special protection as they are especially valuable and are not living under natural conditions. Insect attacks can be overcome by proper spraying; damage by horses and traffic can be prevented by guards around the trunks; suitable laws can be enforced to protect from damage by careless linemen who cut out the tops to pass their wires; sidewalks and curbs can be kept from injuring the roots; and "surgical" treatment should be used when rot or injury makes wounds in any part.

Tree Surgery. With the increasing appreciation of the value of trees, this occupation has become a well developed technical calling. Tree "surgeons" take charge of trimming and pruning work and also treat trees which have been damaged by decay. The decayed limb or stub is removed and, if a cavity has formed, all rotten tissue is carefully cut out, and suitable antiseptics applied, so that no bacteria can remain to cause further decay. After this, the cavity is filled with cement and the limbs properly braced if the decay has caused weakness. Spraying for insect and fungous pests and removal and transplanting of trees is also done by these workmen.

Forestry as a Vocation. For boys who like outdoor life and who are not afraid of occasional hardship, the forest offers several

vocations. A course at one of the forestry schools fits one for expert work as a government forester, manager of private forests, or timber inspector for lumber companies, or for supervision of tree nurseries and re-forestation work.

Either with or without a college training, the occupations of forest ranger or fire warden for the government, or of timber cruiser or inspector for private concerns, offer attractive work for hardy boys. Tree surgery and the care of city trees and private grounds, either alone, or combined with a knowlege of spraying and landscape gardening, are also becoming more important as more people realize the value of their trees.

COLLATERAL READING

Elementary Studies in Botany, Coulter, pp. 419–431; *A First Book of Forestry*, Roth, entire; *Care of Trees*, Fernow, entire; *Handbook of Trees*, Hough, look through; *Nature Study and Life*, Hodge, pp. 365–391; *Principles of American Forestry*, Green, entire; *Trees of Northern United States*, Apgar, look through; *Commerce and Industry*, Smith, pp. 182–208; *Our Native Trees*, Keeler, look through; *American Forestry*, a monthly periodical.

SUMMARY OF CHAPTER LII

THE ECONOMIC IMPORTANCE OF FORESTS

Value of forests.

a. Control of water supply.
b. Benefit to soil (humus).
c. Effect on climate (wind protection).
d. Home for birds and game.
e. Forest products. (See tabulation.)

Enemies of the forests.

a. Man (careless lumbering, fires, etc.).
b. Insect enemies.
c. Fungous diseases.
d. Weather conditions (sleet, frost, snow).
e. Grazing and other animals (rodents).

Protection of forests.

a. Laws enforced and supported by people.
b. Careful lumbering.
c. Re-forestation, planting, etc.
d. Forest reserves held by the Government.
e. Forest rangers to protect reserves.
f. Forestry schools to instruct people.

4. Timber structure.
- a. Grain.
  - (1) Due to annual rings.
    - (a) Bastard.
    - (b) Rift.
  - (2) Due to pith rays.
    - (a) Quarter.
    - (b) Plain.
- b. Heart and sap-wood.
- c. Shrinkage and warping.
- d. Hard and soft woods.
- e. Knots.

5. Street trees.
- a. Value.
- b. Most useful kinds.
- c. Means of protection.

6. Tree surgery.

7. Forestry as a vocation.

CHAPTER LIII

CONSERVATION OF NATURAL RESOURCES

Vocabulary

Exterminate, to completely destroy.
Horticulture, pertaining to gardening.
Entomology, the study of insects.

When our ancestors came to this country, forests covered much of the land, wild animals and birds appeared in countless numbers, the soil seemed inexhaustible, and the rivers poured in mighty volume to the sea.

A seer, whose prophetic vision pictured a time when timber would be scarce, game rare or extinct, soil impoverished, and rivers going dry, would have been laughed to scorn, even if worse did not happen to him. And yet that time is here. The forest, once the enemy of the settler, is now so diminished that it cannot supply his wants.

Animals have retreated before the advance of civilization till many are on the way to extermination. The bison that once covered our western prairie in countless herds now can be found only in protected parks or government reservations. Constant cropping has depleted the once fertile soil, until many regions are deserted, and the cutting of our forests has reduced the flow of many rivers so greatly as to impair their usefulness.

Forest Conservation. The first aim of the early settlers was to clear the land. Forests occupied areas needed for cultivation and sheltered the wild animals and equally wild Indians. The forest bowed before the axe of the colonist.

With the increase of population, the demand for land, lumber, and fuel have so reduced the forest area that conservation of what remains has become a serious national problem.

As early as 1822, De Witt Clinton, Governor of New York State, suggested that some protective action be taken, but it

was 1885 before the state had its first "forest preserve." The American Association for the Advancement of Science urged some form of national forest protection in 1873, but it was not till 1891, during the presidency of Harrison, that the Department of Agriculture began making national forest reserves. Gifford Pinchot of Pennsylvania was one of the leaders in urging adequate forest protection and Theodore Roosevelt was the first of our presidents to take an active interest in conservation as a whole. He called a conference of governors in 1908, created a Conservation Commission and began a definite national conservation policy, not only of forests, but of minerals, soils, waters, and animal life.

The United States now owns about 185 million acres of forest, from which the returns in 1921 totaled $4,500,000.

The whole country originally had 822 million acres of forest. It now contains only 465 million acres of forest land including that which has been cut over or burned. Of this only 135 million acres is virgin forest. There are 250 million acres that are partially productive and 80 million that are practically barren.

Most of the whole area is suitable only for forest and the territory is ample to grow all the timber we need *if it is kept at work growing trees.* That is the problem of forest conservation.

The United States is the largest consumer of wood in the world. In 1923 we used half the lumber, more than half the paper, and two-fifths of the wood in all forms, that were used in the whole world. The amount used is four times the amount replaced by growth, so it is no wonder that the cost of lumber and paper is rapidly advancing.

Causes of Forest Destruction. The cause of this condition is not merely our enormous use of timber. We have taken out the trees as a miner takes out his ore, with no thought of replacement. If we are to have wood and paper much longer, this "timber mining" must stop. Trees are like any other crop and must be replaced as used.

A second cause is waste in the use of lumber. At present over 40% of the standing tree is wasted in manufacture or through careless handling.

Forest fires take terrible toll both of timber and of lives. In 1921 there were 38,400 fires which burned eight million acres. Forest fires cause an average annual loss of $15,000,000. The Peshtigo, Wisconsin, fire of 1875 cost 1500 lives. Fires in Minnesota at Hinckley (1904) and at Cloquet (1918) killed 800 people. One blaze in Olympic National Park burned 14,000 acres in four hours. Such items speak for themselves the need of forest protection.

Fire not only destroys timber, but it prevents natural reforestation by killing all the young trees and burning the seed in the soil. Two-thirds of all forest fires are due to carelessness or worse. Almost the only natural cause is lightning, and that is not very frequent. Fire protection costs from two to three cents per acre per year. The answer is obvious,—individual carefulness and general protection.

The last in the list of these destroyers of the forests are insects and fungous diseases. Except in the case of imported pests, nature's balance protects the forest well enough to preserve it. When foreign forms get a foothold in this country, without their natural enemies to restrict their spread, the results are serious. Losses due to insect attacks on trees and lumber are estimated at $130,000,000 annually.

For twenty years the United States Bureau of Entomology has been devising methods of control for forest insects such as the gypsy moth and western pine beetle.

The chestnut blight, a fungous disease, introduced from eastern Asia about 1892, has almost exterminated that valuable tree. The white pine blister rust, another fungous pest, imported from Europe within the last twenty years, now threatens the existence of the white pine and sugar pine throughout the country.

National quarantine and inspection of all imported trees and plants is our only protection against these unwelcome visitors. Such measures have recently been put in force at our various ports, but irreparable damage has already been done.

The pine rust passes part of its life history on the leaves of the wild currant and gooseberry. Destruction of these plants will stop its spread and should be generally carried out. Over

a million acres have already been cleared of these host plants in the Northeastern and Lake states, at a cost of only thirty-five

Courtesy of "Nature Magazine."

FIG. 193. Flowering dogwood. A beautiful native plant that is being rapidly destroyed.

cents per acre. This is a method of forest protection in which any one who knows a wild currant or gooseberry bush can help.

Means of Forest Protection. 1. *Fire protection.* At present only about half of our useful forest area has any form of fire protection. National, state, and private organizations are all helping. The National Forest Service establishes fire stations

> **SPARE THE DOGWOOD**
>
> None of our native plants is subject to such ruthless destruction as the Dogwood, mostly by well-meaning people who do not realize that our country roads will soon lose their chief spring attraction. The flowers wilt rapidly and are thrown away. ¶ Motorists and others, please help to keep our country roads beautiful.
>
> Chapter 179 Maryland laws provides a fine of from $5 to $25, or 30 to 90 days imprisonment, or both, for taking any tree, shrub, vine, or flower from the property of another without the written permission, or personal supervision of the owner. ¶ A similar law for the District of Columbia and Virginia will be urged.
>
> WILDFLOWER PRESERVATION SOCIETY, WASHINGTON, D. C.

where wardens watch for fires and organize to fight them. Restrictions are made regarding camp fires and notices are posted to warn the public of fire dangers and penalties.

The states of California, Washington, Oregon, Idaho, and the province of British Columbia had 3500 fire wardens in 1923 and handled 7000 fires. The forest area which these men guard is as great as the whole of Great Britain and France together, so their task is not an easy one. In most forest areas the protection is even less.

2. *Selective cutting.* Instead of "mining" the timber, the cut can be limited to mature trees, brush can be removed and seed trees left so that nature can re-stock the forest and continue the crop.

3. *Cut or burned areas can be re-forested.* For this purpose tree nurseries are established by national, state, and private means, where millions of young trees are raised and distributed for planting. The largest nursery in the United States is at

Saratoga, New York. It has a capacity of 29,000,000 trees. The McNary-Clarke Act and various state forestry departments make it possible to obtain trees for planting free of cost.

4. *Reduction of waste in cutting and use.* This rests largely with manufacturers of lumber. By methods now understood, a saving equal to the yearly growth of timber on 170 million acres might be saved. Every one can help, by keeping his house

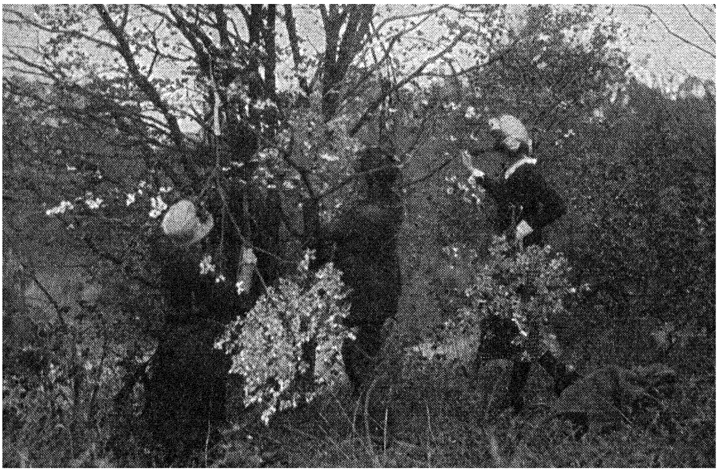


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FIG. 194. Wanton destruction of dogwood trees.

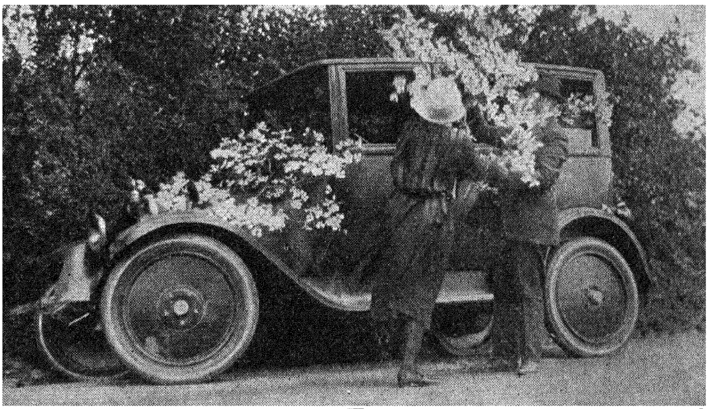
painted so it will last longer, and by not encouraging the enormous waste of paper.

5. *Protection from insects and disease.* The National Forest Service, the Bureau of Entomology, State Departments, and large lumber companies are coöperating in this work. National quarantine helps to prevent importation of foreign pests, and the agencies mentioned above are active in fighting those already here and in furnishing information as to means for their control. Importation of trees for re-forestation is forbidden because of the danger of bringing forest enemies with them.

A letter to the National Forest Service, or the Bureau of

Entomology, or to your State Department of Agriculture or Conservation Commission will bring interesting and helpful information as to local conditions.

Wild Flowers. Wild flowers need protection. The destruction of the forests by lumbering and the frequent occurrence of forest fires have already greatly reduced the areas where they can grow. Thoughtless picking by tourists has been greatly



© *Wildflower Preservation Society, Inc.*

FIG. 195. **Dogwood flowers, gathered to wilt on the way home.**

increased since the automobile has widened the area over which flowers can be gathered.

It is no rare sight to see cars returning from the country loaded with drooping dogwood, azalea, or laurel, none of which will be of even temporary beauty at home. Many flowers once common are now on the way to extermination because of this wholesale picking. Occasionally wild plants are gathered by nursery men and offered for sale. This has resulted in great destruction to some rare native species.

Distribution of wild flowers varies so greatly in different parts of the country that no one list can be made of plants to be protected. There are some general rules with regard to wild flower conservation, however, which all should heed, if we would preserve this source of beauty.

1. Pick no flower that is rare *in your vicinity:* admire them, study them, but "enjoy, not destroy."

2. When picking commoner flowers do not pull up the roots: few wild flowers bear transplanting.

3. When picking flowering shrubs and trees, don't break large branches, or strip the bark.

4. Don't pick more than you can actually save at home. Wilted, suffering blossoms tied to your auto, are no ornament either to your car or your character.

For definite information as to species to be protected in your vicinity, write to the Wild Flower Preservation Society, 3740 Oliver St., Washington, D. C., or the Society for Preservation of Native New England Plants, Boston, Mass.

Several states have laws protecting certain wild flowers, and more are taking such action every year. New York forbids gathering arbutus; California protects the Christmas redberry; Connecticut forbids taking mountain laurel and arbutus for sale unless by consent of the owner of the land; Illinois protects trillium, lady's slipper, gentian, and others; Vermont's list covers a large number of the rarer flowers and ferns; Wisconsin protects the American lotus.

© *Wildflower Preservation Society, Inc.*

FIG. 196. Trailing arbutus. State flower of Massachusetts. Protected by law in New York and elsewhere.

It is not, however, the mere keeping within the law that ought to protect our wild flowers, but rather a regard for the beauty of nature, the rights of others, and our own self-respect.

Conservation of Wild Life. Many valuable species of wild birds, mammals, fish, and other animals have been exterminated

or greatly reduced in number by the advance of civilization and indiscriminate slaughter.

Necessarily, as the country is developed, land is cleared, and the regions where wild animals and birds can live are much reduced. Dams interrupt the streams and factories pollute the waters so that fish can no longer live in them. This would cause sufficient loss of animal life, but greater damage has been done by useless or too extensive slaughter by man.

The destruction of birds, and means taken to preserve them are discussed in Chapter XXXIII.

According to the best authorities it is now a world-wide problem to save many of our wild mammals, especially those which are killed for their fur. During the years 1919–21 over 100 million skins were sold and many more were taken which were unfit for sale.

Among these were 14 million muskrats, 24 million moles, 13 million opossums. At such a rate of destruction it is no wonder that fur bearers are getting scarce. Much of this slaughter is due to the silly habit of wearing "summer furs," which are worse than useless. Man has no real excuse for wearing fur at any time, since wool makes a better winter garment and does not require the death of its producer.

Several animals killed for food or sport are in danger of total destruction in many regions. The bison is gone except for a few herds under government protection. Elk and deer are now scarce in places where they were once abundant. The federal and state governments have begun to realize the condition and to take measures to correct it. Some states have excellent laws wholly forbidding the killing of certain animals and restricting the hunting season for others, so that they shall not be killed during the breeding period. Many states have laws providing for humane methods of trapping, so that animals are not left to die in misery in the grip of the trap. Certain types of traps are forbidden and traps must be visited often enough to prevent unnecessary suffering.

Application to your own State Department of Agriculture or Conservation Commission will secure information as to the

laws which regulate these matters in your own state. The United States Department of Agriculture also publishes a summary of all the state laws, which is revised each year.

The federal government has twenty-eight game sanctuaries or reservations where both mammals and birds are protected. Seventeen of these are National parks and are under the supervision of the Department of the Interior, the largest being Yellowstone Park with an area of nearly two million acres.

The Forest Service has charge of five preserves, the Biological Survey controls four more, and the Bureau of Fisheries has two in Alaska, totaling all together thousands of acres. Some of the animals specifically protected are bison, elk, antelope, deer, mountain sheep, sea otters, seal, sea lions, bear, caribou, moose, beaver, and goats.

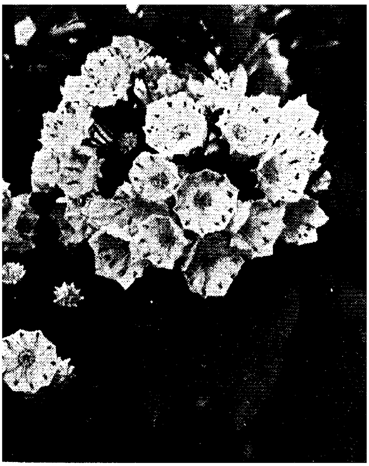


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FIG. 197. Mountain laurel. State flower of Connecticut.

The United States Biological Survey has general supervision of the conservation of birds and mammals. It controls the national reservations and administers laws pertaining to interstate commerce in game. It also investigates the relation of animals to agriculture, surveys the range of animals and plants, and publishes reports on these and related topics.

The Department of the Interior, which has charge of the national parks, also aids in mammal conservation work. The Department of Agriculture, which includes the Forest Service and Biological Survey, publishes many reports on animal value and conservation. State conservation commissions perform similar service in many states.

The Society for the Prevention of Cruelty to Animals protects domestic animals from the abuse or ignorance on the part of their owners. It especially protects horses from overloading or cruel treatment and has secured the passage of local regulations in many cities.

Fish Conservation. The United States produces about two billion pounds of fish every year. The total value is not far from one hundred million dollars and the industry gives employment to over 200,000 persons. This enormous consumption, together with the pollution of streams, reduction of flow, and construction of dams, have all combined to reduce the number of many valuable fish.

To check the destruction of this valuable source of natural wealth, various means are used. Chief among these is the United States Bureau of Fisheries which is a division of the Department of Commerce. This bureau maintains forty stations and hatcheries where studies are made as to breeding habits, food, diseases, and parasites. All factors that will check the decrease in food-fish are investigated and experiments in fish culture are carried on.

Fish Hatcheries. At the hatcheries, quantities of fish eggs are hatched and the young fish supplied to stock waters in which the native fish are decreasing. As many as four billion eggs and young fish have been handled in a single year. Shad, trout, lake trout, and salmon are among the fish thus distributed. Many states also have Fish Commissions or Conservation Departments which deal with similar problems and conduct hatcheries for re-stocking their waters; it is frequently possible to obtain eggs or young fish at very little cost, provided certain protective conditions are complied with.

There are usually state laws regulating to some extent the following items in fish protection:

1. Closed seasons for various species especially during breeding.
2. Restriction as to size and number to be taken.
3. Forbidding use of explosives or draining ponds to kill fish.

4. Restriction as to use of nets and mechanical devices.
5. Fish ways required in dams.
6. Pollution by factories or sewage is regulated.

The particular laws of your own state can be had on application to the state game warden or commissioner.

Fishing is good sport and with a little care, the streams need never be exhausted. Obey the laws. Catch only what you personally can use. Kill the fish which you keep; don't leave them to die in slow misery. When putting back under-sized fish, *wet your hand* so as not to scrape off the protective film that covers the scales. If this is removed disease usually kills the fish, even though carefully unhooked.

Federal Protection. An idea of the extent to which the federal government is interested in the preservation of wild life may be gained from the fact that a mere list of the Game Preserves, Bird Refuges, and Mammal Sanctuaries controlled by the United States occupies a bulletin of eleven pages.

Various government departments are interested in this important work as shown by the summary below:

Department	Number of Refuges
Department of Agriculture	
Biological Survey	71
Forest Service	5
Department of Commerce	
Bureau of Fisheries	2
Bureau of Lighthouses	5
Department of Interior	
National Park service	25
Department of the Navy	4
Department of War	4

Conservation of Crops. Agriculture is the basic industry of any country. Food must be had and it must be provided by the farmer from the soil. Here conservation is concerned with preservation of the soil itself and with protection of the crops raised upon it. *Soil conservation* is assisted by several agencies. The Departments of Agriculture, both national and state, are constantly experimenting with fertilizers, crop rotation, drainage, and similar problems and their results are published for the help of all who will use them.

The National Reclamation Service deals with irrigation, building dams for water conservation and opening new areas for agriculture. The Forest Service aids in soil preservation because of the close relation between forest growth and drainage control. Where forests are cut off, soil is washed away, floods are increased, and agriculture hindered.

Crop Protection. The crops themselves face two serious enemies, insects and fungous diseases.

Here are a few of the more disastrous insects, together with the damage they do to our crops. The figures are conservative estimates made by the U. S. Department of Agriculture and apply just to the United States:

Grasshoppers	$ 50,000,000
Chinch bugs	60,000,000
Hessian fly	40,000,000
Codlin moth	20,000,000
San José scale	10,000,000
Cotton boll weevil	300,000,000
Cotton boll worm	12,000,000
Potato bug	8,000,000
Grain weevil	10,000,000

Altogether the annual board bill levied by insects on our food crops is around $2,000,000,000. This takes no account of the damage done in many other fields of their activity, such as the great onslaught against our forests.

Insects destroy each year crops of value greater than all the money spent in schools and colleges during the same time. They cost the country twice as much as is spent on both the army and navy together. This is in addition to their harm in relation to disease.

Of these pests 85% are immigrants from other countries where their natural enemies hold them more or less in check. The cotton boll weevil came from Mexico, and now threatens the whole cotton area of the United States. The Hessian fly, which is one of our worst wheat pests, came over in straw brought by soldiers in the Revolutionary war. The European corn borer arrived from southern Europe on imported broom corn in 1909 and now is a serious pest on corn, beans, beets, and potatoes.

The gypsy moth and brown-tail moth also came from Europe to prey upon our fruit and forest trees.

The San José scale insect, which attacked the fruit trees of California, came from Japan and at one time bid fair to destroy

Courtesy of "Nature Magazine."

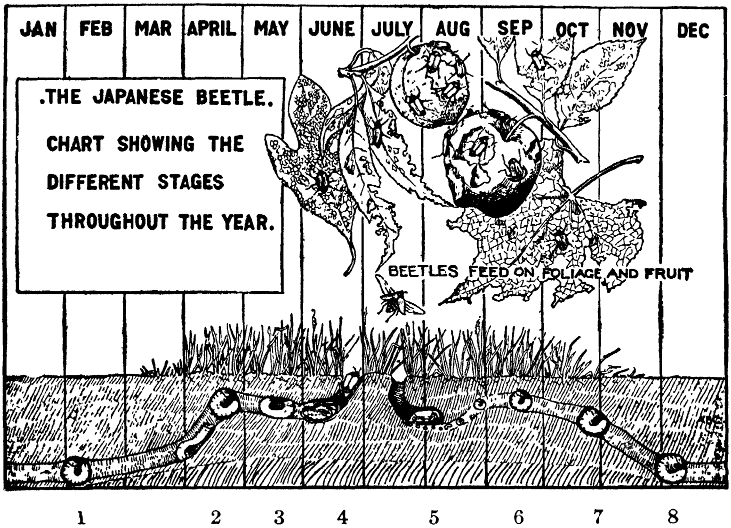
FIG. 198. The showy lady's slipper. A native American orchid that is in danger of extermination.

the industry. Two beetles from Australia and a parasitic fly from Africa were found which would destroy the scale, and by their timely introduction this menace was averted.

The Oriental fruit worm and the Japanese beetle are also

immigrants from Japan. They attack orchard and garden crops and are spreading through the eastern states. Natural enemies are being sought but their ravages are not checked as yet.

Fungous diseases also cause great damage. Wheat rust



Courtesy of A. B. Champlain.

Fig. 199. (1) Grub in winter cell. (2) Grub comes up again near surface and feeds. (3) Grub forms cell and prepares to pupate. (4) Grub changes to pupa, then to adult beetle which comes out of ground and feeds on fruit and leaves. (5) Beetles lay eggs in ground preferably in soil covered with vegetation. (6) Young grubs hatch and feed on decaying vegetation and live roots. (7) Grubs continue to feed in soil and grow rapidly. (8) Grubs go down 3 to 12 inches and make winter cells.

destroys $50,000,000 worth of grain each year. Citrus canker which came from Japan causes a $20,000,000 loss to orange and grape fruit in the Gulf States. Potato wart, grain smuts, and other fungi do vast damage. There are 238 fungi that attack crop plants to some extent.

Remedies. To combat these insect enemies, the United States spends $3,500,000 annually. The various states spend great sums and the cost to individuals for spraying and other preventive measures is enormous.

The Department of Agriculture, acting through the Bureau

of Entomology and the Horticultural Board, does most of the federal work. States also maintain Departments of Agriculture and State Entomologists for similar purposes.

The work in general consists of investigation of the habits of harmful insects, development of methods of control, and publication of all helpful information. Experiment stations and laboratories are provided and experts are trained in State Agricultural Colleges to carry on the battle.

The best remedy for immigrant pests is to discover their natural enemies abroad and introduce them in this country. For this purpose government experts are constantly employed in foreign countries seeking natural enemies of the harmful species.

Inspectors are stationed at ports of entry to examine imported plants for possible pests. Many fruits and plants are excluded by quarantine regulations because of the danger of introducing harmful insects.

An embargo on Malaga grapes from Spain is maintained because of the presence of the Mediterranean fruit fly. All fruits, except pineapples and bananas grown in the Hawaiian Islands, are shut out from the American market because of the Mediterranean fruit fly and the melon fly. Several species of Mexican fruits are excluded because of the Mexican fruit fly.

Quarantines within the United States itself are maintained, prohibiting the movement of cotton from isolated points in Texas, where infection has been found; corn and broom corn, sorghums and Sudan grass from infested areas in Vermont, New York, Pennsylvania, Ohio, and Michigan, on account of the European corn borer; and in certain counties in New Jersey, Pennsylvania, and Delaware, because of the Japanese beetle, which affects farm products between June 15 and October 15.

Conservation of Health. Conservation is usually thought of as applying to our forests, animals, soil, or other items of so-called "natural wealth." The condition of the people who use these resources is more important, and health conservation is of importance to individual, state, and nation.

The physical examinations that were made during the war opened the eyes of the public to the fact that many of our

citizens, even at the age of greatest vigor, were unfit to serve their country because of physical defects and ill health.

The National Health Council, various life insurance companies, and large industrial concerns have compiled statistics showing a financial loss of over $3,000,000,000 a year due to preventable disease. This total is staggering and gives strength to the growing idea of health conservation both as a personal and national problem. The matter has become of international importance and the League of Nations has taken action to aid in combating yellow fever, malaria, cholera, typhus fever, hookworm, and leprosy.

Federal Departments. Most progressive nations have departments devoted to health conservation. In the United States various federal agencies have to do with this matter. At the ports of our country immigrants are inspected and if suffering from certain diseases are refused entrance. Passengers on all incoming ships may have to pass a "quarantine examination." In this way many dangerous diseases of the old world have been kept from our shores.

Federal and state authorities have waged a war against immigrant and native rats, which are often disease carriers, and ships are rid of these pests or measures taken to prevent their landing.

The national government, by means of its food and drug laws and meat inspections, is doing much to see that its citizens have a healthful food supply. Federal research laboratories are maintained where disease prevention, transmission, and cure are investigated. The results are published and often embodied in health laws and regulations.

The Army and Naval hospital services have also done much valuable work in this line, notably in yellow fever and typhoid fever prevention.

State Departments. State health conservation deals with matters that may not come under federal control. Factory conditions, hours of labor, child labor, housing conditions, and accident prevention are subject to state regulation, in the interest of better health. State laboratories furnish serums and

vaccines of tested efficiency and publish much valuable information.

Many states have a Board of Health or similar department which does research work, publishes bulletins on care and prevention of disease, aids in controlling epidemics, and examines and licenses persons who wish to practice medicine.

City and town authorities come even closer to the individual and his health. They regulate water, milk, and food supplies by laws and inspections. Sewage and garbage disposal are supervised in the interests of health. City laboratories examine foods, investigate cases of infectious disease, furnish vaccines and serums, inoculate patients for various diseases, and assist the doctors in controlling epidemics. Many cities wage systematic warfare on rats, mosquitoes, flies, and other germ carriers.

Tenement house, market, and factory inspection are under city control. People who sell or handle foods are subject to examination for infectious disease. Sanitary conditions of living are enforced when people are too ignorant or careless to look out for themselves. Quarantine of infectious disease is another city function.

Visiting Nurses. Many cities, counties, and towns provide visiting nurses who instruct and aid, especially in child welfare work. Free clinics are often provided where treatment for disease, dental trouble, infant illness, or mental disorders is rendered. Special instruction in the care of babies is frequently given and pure milk stations are furnished for their safety.

Health conservation through the schools has the support of both state, city, and town. The study of hygiene is required, and care of teeth, posture, and general health are taught. Pupils are inspected for defects of teeth, eyes, and ears. Diseased tonsils, adenoids, and glands are discovered and treatment often given free. School nurses, dentists, and doctors are frequently employed. Most cities and towns provide hospitals; many have public baths, playgrounds, and parks, all of which help in preserving the health of the citizens.

Persons who are mentally or physically defective are cared for in state and city institutions adapted to their particular trouble.

The insane, epileptics, feeble-minded, and people suffering from tuberculosis are often thus looked after.

Tuberculosis is such a prevalent and serious disease that state, city, town, and private means are all enlisted in combating this "white plague." Separate state tuberculosis departments are sometimes instituted; sanatoriums are maintained; and information is published to help persons suffering from this disease.

The Red Cross, through the sale of its Christmas seals and in other ways, is doing much helpful work. Life insurance companies and private individuals are helping in the campaign. Figures for 1924 show a decline of 53.4% since 1911 in the death rate due to tuberculosis among 16,000,000 policy holders of the Metropolitan Life Insurance Company. The government and the American Legion are maintaining sanatoriums to treat this disease among the soldiers.

Private Means of Health Conservation. There are many private agencies engaged in health conservation, of which only a few can be named here. Space forbids taking up their work in detail. A letter to any of them will bring helpful and interesting information in their various lines of work.

Rockefeller Institute of Medical Research	New York City
Rockefeller Sanitary Commission	" " "
Life Extension Institute	" " "
Millbank Memorial Foundation (Tuberculosis)	" " "
Memorial Institute for Infectious Diseases	Chicago
Pasteur Institute	Paris
Russell Sage Foundation (Dept. of Child Helping)	
Child Health Organization	
American Society for the Prevention of Cancer	
Carnegie Institute (headquarters)	Washington
Maintains Nutrition Laboratory	Boston
Dept. of Experimental Evolution	Cold Spring Harbor, L. I.
Dept. of Plant Physiology	Tucson, Ariz.
Metropolitan Life Insurance Co.	New York City
Prudential Life Insurance Co.	" " "

With all these organizations, public and private, working for health conservation, still success rests with the individual. If each of us lives as well as he knows how: thinks, eats, sleeps,

works, and plays in accordance with his best knowledge, then, and then only, will health be conserved. Not otherwise, no matter how much the government may do for us. It cannot save us from ourselves.

"It is within the power of man to rid himself of every parasitic disease," wrote the great Pasteur. This should be the ideal toward which we all are working.

COLLATERAL READING

A letter to any of the departments mentioned below will bring valuable information, free, on the subjects dealt with in the various bureaus. Ask also for publication lists and from them select the ones that interest you.

Department of Agriculture, Washington, D. C.
- Bureau of Biological Survey.
- Bureau of Entomology.
- Forest Service.

Department of Commerce, Washington, D. C.
- Bureau of Fisheries.

Department of Interior, Washington, D. C.
- National Park Service.

U. S. Dept. of Agriculture, Separate No. 886 "Timber, Mine or Crop."
" " " " , " No. 835 "Wood for the Nation."
" " " " , Farm Bulletin, 1444 "Game Laws for 1924–25."
" " " " , Biological Survey No. 62 "Federal Game Laws."
" " " " , " " No. 33.
" " " " , "Conserving our Game & Birds" (Goldman) 1920.

New York State Conservation Commission publishes "Friends and Foes of Wild Life," "State Parks & Reservations," etc.

New York State Dept. of Health publishes "Radio Health Talks," "Regulations for Disinfection," "Toxin-Antitoxin & Schick Test," pamphlets on many infectious diseases, etc.

New York State Dept. of Labor publishes "Industrial Hygiene Bulletin."

Metropolitan Life Insurance Co. publishes "War on Consumption," "Hookworm Disease," "Typhoid Fever," "Smallpox," etc.

New York Life Insurance Co. publishes "Alcohol and Longevity."

Wildflower Protective Association, 3740 Oliver St., Washington, D. C. has many pamphlets on its work.

American Museum of Natural History has wonderful health exhibits and publishes "Guide to Health Exhibits."

The following are four books that might well be read entire:
- "Our Vanishing Wild Life," W. T. Hornaday.
- "Wild Life Conservation," W. T. Hornaday.
- "Conservation of Natural Resources in U. S.," VanHise.
- "Our Wasteful Nation," Cronau.

Also "Practical Zoölogy," Hegner, pp. 450–471.

SUMMARY OF CHAPTER LIII

CONSERVATION OF NATURAL RESOURCES

1. Necessity.

2. Conservation of forests.
- a. Present condition.
- b. Causes of forest.
- c. Means of protection.
  - (1) Fire protection.
  - (2) Limited cutting.
  - (3) Re-planting of trees.
  - (4) Reduction of waste.
  - (5) Protection from pests.

3. Conservation of wild flowers.

4. Conservation of wild life.
- a. Causes of destruction.
  - (1) Clearing of land.
  - (2) Hunting for fur.
  - (3) Hunting for food and sport.
- b. Means of conservation of mammals.
  - (1) Game laws.
  - (2) Game sanctuaries.
  - (3) Work of government departments.
    - (a) Biological Survey.
    - (b) Forest Service.
    - (c) National Park Service.
    - (d) State and local agencies.
  - (4) Society for Prevention of Cruelty to Animals.
- c. Means of conservation of fish.
  - (1) Work of Bureau of Fisheries.
  - (2) State and national hatcheries.
  - (3) Laws regulating fishing.
  - (4) Laws regulating the use of waters.

5. Conservation of agricultural resources.
- a. Soil.
- b. Crops.
  - (1) Insect enemies.
  - (2) Fungus enemies.
  - (3) Means of protection.
    - (a) Work of National and State departments.
    - (b) Introduction of natural enemies.
    - (c) National and state quarantines and laws.

6. Conservation of health.
- a. International activities.

b. National activities.
    (1) Immigrant inspection and quarantine.
    (2) Campaigns against rats and insects.
    (3) Food and drug laws; food inspections.
    (4) Research laboratories.
c. State activities.
    (1) Regulation of living and working conditions.
    (2) Laboratories (serums, vaccines).
    (3) Board of Health (research, publications, etc.).
    (4) Licensing physicians.
d. Local activities (city, county, town).
    (1) Water and milk inspection.
    (2) Sewage and garbage disposal.
    (3) City laboratories (test for disease, serums, etc.).
    (4) Campaigns against rats and insects.
    (5) Inspection of markets, tenements, food dealers, etc.
    (6) Sanitary and plumbing inspection.
    (7) Quarantine regulations.
    (8) Visiting nurses; free clinics.
    (9) School instruction, examination, nurses, doctors.
    (10) Hospitals; public baths; parks; playgrounds.
    (11) Institutions for special diseases.
e. Private activities.
    (1) Institutions for research and cure.
    (2) Child welfare organizations.
    (3) Work of American Red Cross.
    (4) Army and American Legion hospitals.
    (5) Life insurance companies.

CHAPTER LIV

TOBACCO AND TABLE BEVERAGES

Vocabulary

Nicotine, a harmful ingredient of tobacco, an alkaloid narcotic.
Acreolin, an irritating substance in tobacco smoke.
Narcotic, a substance tending to deaden nerve action and produce sleep or stupor.
Caffein, an alkaloid found in tea, coffee, and cocoa.
Cocaine, an alkaloid from leaves of coca plant. No connection with cocoa.
Morphine, an alkaloid from the opium poppy juice.

The damage done by alcohol and tobacco are often dealt with in the same chapters and spoken of together, as if they had much in common. This is unfortunate, for young people, seeing men little harmed by use of tobacco, will assume that alcohol is no worse, and come to very wrong conclusions.

Tobacco does harm enough and wastes resources enough, but we ought not to let alcohol assume any comparison of their relative danger. This is not to excuse the use of tobacco, but to prevent young persons from concluding that one is no more harmful than the other, merely because they are often spoken of together. A comparison of this chapter with the one on alcohol will make the matter sufficiently plain.

Tobacco. It is well known that protoplasm in a young plant or animal is more easily injured than when it has attained full growth. The seedling plant is more easily killed by frost or heat; the chick is harmed by exposure that would not be felt by the hen; the human infant is injured by various things which would not affect the adult at all. This is not alone because of the difference in size of body, but the growing active protoplasm is much more sensitive than when it reaches maturity, and therefore is much more seriously affected by stimulants and narcotics.

Herein lies the chief biologic argument against the use of tobacco. Tobacco contains a harmful alkaloid, nicotine, and also produces when burned carbon monoxid, which is a poisonous

gas. In addition, if the smoke is inhaled, a substance called acreolin, together with the smoke particles, increases the irritating effect.

If tobacco is used by boys who have not attained the full physical maturity of twenty years or more, these substances produce numerous and serious results which should at least postpone the indulgence till later life.

Tobacco is narcotic in effect; narcotics tend to decrease bodily efficiency and hinder growth. The physical effects, while not to be compared with the ravages of alcohol, are nevertheless important and should be noted.

Cigarettes. The increasing use of cigarettes, especially by young people, is to be deplored. Cigarettes are less apt to cause severe illness when their use is begun and this, together with their cheapness, has made them popular with growing boys and girls. One is apt to smoke more tobacco and use it during more hours by smoking cigarettes than in any other form and for this reason they are the more dangerous.

Also more acreolin is produced by the slow burning paper, and the smoke is more likely to be inhaled, both of which facts add to the harm likely to be done by the habit. Recent investigations show that the eyes are especially affected.

Cigarettes continue to burn when thrown aside and this is the cause of millions of dollars worth of fire losses.

Irritation to Mucous Membranes. Smoking certainly irritates throat and lungs, especially if the user "inhales." This opens the way for germ attack in addition to the harm done to the tissues by smoke and acreolin. The eyes are also irritated especially when one smokes and reads at the same time.

Effect on Endurance. Any narcotic interferes with nerve control, especially of heart and lungs. That this is the case with tobacco has been abundantly proven by experiment. For this reason, no trainer permits smoking by members of his team, knowing well that endurance and "wind" cannot be developed when tobacco is used. The United States forbids its use at West Point and Annapolis because of its harmful effects, both physical and mental. Figures obtained from six leading colleges show

that of those who "made the team" just twice as many were non-smokers.

Effect on Growth. In some cases the use of tobacco seriously affects digestive processes and in its early use the stomach usually revolts at its presence. The effect of excessive smoking may even extend to the vital activities of protoplasm and actually "stunt the growth" of various organs. This is common where it is used when very young.

Effect on Mental Development. Many investigations at different schools and colleges have thoroughly proven that the use of tobacco affects the brain enough to impair scholarship. Dr. Meylan, physical director at Columbia, reaches these conclusions:

1. Smokers averaged eight months behind non-smokers in their advancement.
2. Scholarship standing of smokers was distinctly lower.
3. Use of tobacco by students is closely associated with lack of ambition, application, and scholarship.

Another investigation shows that:

1. Smokers average lower in grades.
2. Smokers graduate older.
3. Smokers grow more slowly in height and weight.
4. 95 per cent of honor pupils are non-smokers.

Dr. Andrew D. White, who for twenty years was president of Cornell University, says, "I never knew a student to smoke cigarettes who did not disappoint expectations, or to use a common expression, 'kinder peter out.' I consider a college student who smokes as actually handicapping himself for his whole future career." Dr. White was not a fanatic and used tobacco himself after he reached middle life.

In spite of such evidence boys certainly will note many successful men, perhaps their own fathers, who do not seem to be harmed by smoking, and, forgetting the difference in age, will draw wrong conclusions. Tobacco would do less harm if it were more harmful, so that its effects could be more easily traced.

For such prospective smokers there are other arguments.

1. Tobacco certainly becomes a "habit." Do you want to be "held" by a useless and probably harmful drug?

2. Tobacco is offensive to many people. Are you so selfish as to gratify your taste to the discomfort of others?

3. Tobacco decreases your personal attractiveness. The odor of breath, hands, and perspiration, the stains on fingers and teeth, do not improve your personality.

4. Tobacco is expensive. A regular smoker spends more than he realizes on his indulgence. Don't you think you could have more fun for your money?

5. The growth and manufacture of tobacco wastes soil, labor, and money, sorely needed in productive lines of industry.

6. Smokers cause about one-fourth of the fires, both in buildings and forests. You can scarcely find a factory without its "No Smoking" signs on this account.

To quote from another authority in conclusion:

"Whatever difference of opinion there may be regarding the effect of tobacco on adults, there is complete agreement among those best qualified to know, that the use of tobacco is in a high degree harmful to children and youth."

Tea and Coffee. To a degree much less than tobacco, these beverages contain harmful alkaloids. As with tobacco, their use is certainly not wise for the young. With adults, moderate indulgence may do no harm or may even be beneficial, though this is a matter which every person must decide for himself.

Neither has much food value, both are rather costly, and both tend to become habits. On the other hand they sometimes seem to soothe the nerves (which ought not to need soothing), or to permit one to continue work when nearly tired out, which also is a rather doubtful benefit.

Cocoa and Chocolate contain less alkaloids and a great deal of fat, hence are real foods. More people should learn to properly prepare them and then tea and coffee would be less used, with benefit to all concerned.

It seems almost unnecessary to say that no medicine or beverage containing alcohol, opium, morphine, chloral, cocaine, or any of their derivatives should *ever* be used except by advice of a reputable physician. The awful danger of forming a "drug habit" in this way has led to stringent laws, which we should all help enforce.

TABULATION OF SOME COMMON DRUGS

Stimulants	Narcotics
Alcohol, slight first effect	Alcohol, general effect
Alkaloids in tea, coffee, and cocoa	Nicotine
Strychine	Opium, morphine, etc.
Nux vomica	Chloral
Gentian	Cocaine, heroin, etc.
Quinine	Codeine

COLLATERAL READING

A Handbook of Health, Hutchinson, pp. 89–93, 103–107; *The Human Mechanism*, Hough and Sedgwick, pp. 357–362, 377–379; *Applied Biology*, Bigelow, pp. 551–553; *The Next Generation*, Jewett, pp. 136–144; *Applied Physiology*, Overton, see index; *General Physiology*, Eddy, see index; *Principles of Health Control*, Walters, see index; *Civics and Health*, Allen, pp. 363–368.

SUMMARY OF CHAPTER LIV

TOBACCO AND TABLE BEVERAGES

1. Comparison of Alcohol and Tobacco.

2. Tobacco.
- a. Physical objections to its use.
  - (1) Sensitiveness of growing protoplasm.
  - (2) Smoking exposes to nicotine, carbon monoxide, acreolin, etc.
  - (3) General narcotic effect.
  - (4) Irritation to mucous membranes.
  - (5) Reduces endurance.
  - (6) Interferes with growth and digestion.
  - (7) Seriously impairs mental development and scholarship.
- b. Social objections to its use.
  - (1) It becomes a useless habit.
  - (2) It is a selfish habit, because offensive to many.
  - (3) Decreases personal attractiveness (odor, stains, etc.).
  - (4) Unnecessary expense.
  - (5) Wastes soil, labor, and money in its production.
  - (6) Danger in causing fires.

3. Tea and Coffee.
- a. Contain harmful alkaloids.
- b. Very slight food value.
- c. May harm digestion or nerves.
- d. Certainly not good for young people.
- e. Unnecessary expense.

4. Cocoa and Chocolate.
- a. Contain little alkaloid and much fat. b. Useful as foods.

CHAPTER LV

ALCOHOL IN RELATION TO BIOLOGY

Vocabulary

Acceleration, speeding up action.
Morbid, abnormal.
Predisposition, tendency toward.
Therapeutics, curative medicine.
Stimulant, a substance which temporarily increases nerve activity.

The chemist would say that "alcohol" is one of a number of similar compounds, containing carbon, hydrogen, and oxygen in the proportions C_2H_6O and would insist that we call it "ethyl alcohol" or "grain alcohol" to distinguish it from wood alcohol, glycerin, and many other similar forms. The physiologist or physician would tell us that it is a narcotic poison in its action on the tissues, disturbing especially the nervous system.

The reason that this substance demands a chapter in a biology text is that man, from the earliest times, has used this drug because of its intoxicant effects, until now its bearing upon the development of the human race has become one of the greatest biological problems.

Alcoholic beverages may be classed roughly in three groups:

1. Beer (2–5 per cent alcohol) made from fermented barley.
2. Wine (15–20 per cent alcohol) from fermented fruit juices.
3. Whiskey (30–50 per cent alcohol) from either source, but distilled to increase its strength.

In ancient times before modern methods of manufacture were invented, wine was a comparatively harmless drink, but now both the amounts used and the alcohol contained have so increased that alcoholic liquors are a biological question of the first magnitude. In the discussion that follows it must not be forgotten that alcohol is an indispensable chemical substance used as a solvent, preservative, and raw material in numerous industries. These are matters that concern the manufacturing

chemist, while biology has to do only with its effect when used as a beverage by man.

Physical Effects. In the first place alcohol, although oxidized in the body, cannot be classed as a food, yet is often so called by people who should know better. A food is "a substance which when assimilated in the animal body builds tissue or produces energy without harming the organism." Alcohol harms the organism in various ways as will be shown, hence cannot properly be classed as a food.

Alcohol is chiefly oxidized in the liver and the heat is lost by the rush of blood to the skin (Atwater). This oxidation produces uric acid which overworks the liver and kidneys, to the detriment of both (Beebe).

Dr. Irving Fischer of Yale says, "These heat values cannot be expended without at the same time poisoning the system with alcohol, so it is not even technically correct to count the heat value of alcohol as such."

Dr. Von Bunge, chemist of University of Basel, says, "Alcohol produces energy (heat) but increases the loss of heat still more; the net result being a lowering of temperature; the feeling of warmth is an illusion due to narcotic action on the nerves."

The same authority also says, "Beer does contain small amounts of dextrine and sugar but we already eat too much of these, and, supplied by beer, they are fabulously expensive; beer does not promote digestion."

Despite this claim that alcohol is a food, no one really thinks of using it for nourishment, but rather because of its narcotic effects on the nerves. Opium and phosphorus are also oxidized in the body, but no one claims food value for these poisons, and alcohol belongs in the same class.

Alcohol, then, is not a food, because

1. It produces a net loss of energy, though oxidized.
2. It does not build tissue, but poisons it.
3. It furnishes its small apparent energy at great expense.

Effect on Nutrition. Alcohol withdraws water from all food stuffs and acts chemically on protein, exerting a hardening action in both cases and hindering the work of the digestive

fluids. In the same way it hardens and irritates the tissues lining the alimentary canal, especially the walls of the stomach, where it always interferes with normal action, and may cause serious disease. Alcohol certainly increases the flow of digestive fluids and its medicinal use was based largely on this effect until it was found that the abnormal flow caused a lack of fluids later. Glands that had been "stimulated" by alcohol refused to respond to the presence of mere food.

"Acceleration of gastric action is counter-balanced by inhibitory effect of alcohol on the chemical processes of digestion." —Chittenden.

The direct effect of alcohol is shown most plainly in its action on the liver, where, as already mentioned, it overtaxes and irritates that important organ. Over 60 per cent of deaths due to cirrhosis of the liver are cases where the disease was caused by alcoholic liquors.

Effect on Circulation. The chief effect of even small amounts of alcohol is to paralyze the vaso-motor nerves which control the blood flow and heart action.

Thus with relaxed artery walls and lessened heart regulation, the pulse is quickened, the blood is driven to the skin and mucous membranes, and the familiar "stimulant" effects are produced. Notice in the first place that this is due, not to any "stimulation" at all, but to a *deadening* of the nerve controls, and second, that, although the skin feels warm, due to the excess blood, it is actually losing heat, because so much blood has been brought to the surface.

"The general temperature is always lowered."—Macey.

Not only this, but with continuous use alcohol *keeps* the capillaries relaxed, causing reddening of the skin and inflammation of the mucous linings, both of which favor the attacks of various diseases.

Alcohol deadens the control centres and so the circulatory organs "run away"; they are NOT stimulated. One might as well talk about stimulating a steam engine by removing the governor. Yet this is a very common error.

Alcohol is never a stimulant, but always a narcotic, producing

its results by its interference with nerve control in every case. "No amount of alcohol, however given, can increase the amount of work done." —Dr. Woodhead, Cambridge University.

Aside from its interference with the normal distribution of blood and consequent predisposition to colds and inflammations, its excessive use may permanently harden the arteries (arteriosclerosis), or affect the heart muscles (fatty degeneration) though these are not so important from a biologic standpoint as the more general effects which even occasional use produces.

Effect on Respiration. The interference with blood regulation is particularly harmful in the lungs, causing inflammation and diminishing resistance to pneumonia and congestive diseases. At the same time connective tissue is increased and the actual lung capacity is lessened. A curious chemical result also ensues; alcohol is so easily oxidized, that it uses oxygen actually needed to release the energy from real foods. This appears to be a "stimulation" of the breathing process, when as a matter of fact, the added air is not sufficient to oxidize the alcohol alone. The final result is loss of energy from the unoxidized food in addition to the heat wasted by way of the skin, as shown above.

Effect on Excretion. This improper oxidation and interference with blood flow and skin functions produce excess of uric acid and other wastes for the kidneys to dispose of, resulting always in impaired function and sometimes in serious disease. Rheumatism, Bright's disease, and fatty degeneration of the kidneys may be caused or encouraged by excessive use of alcohol.

Effect on Nervous System. As has been shown, alcohol's principal line of attack is by way of the nervous system and it is here that its effects are most serious. In the evolution of the nervous system the centres of control develop in this order:

1. Heart and circulation control.
2. Respiration.
3. Walking and large muscles.
4. Speech and other senses.
5. Moral and intellectual control.

The peculiar harm of the narcotic action of alcohol is, that it impairs these nerve centres in reverse order. The higher emotions, moral sense, modesty, judgment, and self-control are first attacked, and from this effect arises the awful record of alcohol as a cause of immorality and crime. With the body control but little impaired and able to carry out the impulses of a disordered mind, a man will commit crimes or perform acts which he never would have thought of doing if his self-control had not been affected by this dangerous narcotic drug. Further effects of alcohol are shown when the speech and sight centres are attacked, as the thick speech and double vision of the alcoholic victim are all too familiar evidence. Next the walking and other large muscles are affected and the staggering gait and uncertain movements are observed. Finally, the breathing is interfered with, the heart action partially or wholly paralyzed, and the condition of "dead drunkenness" or even death ensues.

If the order of its effects were reversed, alcohol would not be so dangerous, because the body would then be unable to carry out the demands of the deranged brain. Unfortunately, this is not the case, and herein lies one of alcohol's greatest biological dangers. Furthermore, alcohol actually attacks the brain tissue, causing irreparable harm and producing the morbid desire for more liquor so characteristic of the victims of this awful habit. The apparent "nerve stimulation," so frequently mentioned, is merely the paralysis of sense and self-control, leaving the body to act, often more violently, it is true, but never increasing its effective energy.

"Even the feeling of rest due to slight indulgence in alcohol is caused by its anæsthetic effect upon the sense of fatigue, which is the safety valve of the human machine."—Von Bunge.

The whole case is thus summarized by Dr. Brubacher of Jefferson Medical College, Philadelphia, "Alcohol deranges the activity of the digestive system, lowers the body temperature, impairs muscular power, diminishes the capacity for mental work, and leads to actual changes in the tissues of the brain and other organs."

Alcohol and Disease. Not only does alcohol have the specific effects already mentioned but injures the general health in two ways:

1. It is a direct cause of certain diseases.
2. It lowers bodily resistance to nearly all diseases.

Examples of the first case have been mentioned in connection with the various organs, such as:

Heart diseases, enlargement or fatty degeneration.
Inflammation of the liver, "hobnailed liver."
Inflammation of the stomach, indigestion.
Insanity.

Far more important, however, is the effect of alcohol in lowering the resistance of the body to external attack and in creating abnormal internal conditions, which make the course of many diseases more serious, though they were not *caused* by the use of liquor.

This predisposition to disease is brought about in two ways:

1. The white corpuscles, which defend us against bacterial attack, are destroyed, and the ability of the blood to provide antitoxins is lessened.

2. By the various disarrangements of nerve control, blood and food supply, alcohol overstrains certain organs, and interferes with the action of others, so that diseased conditions are produced.

Statistics compiled by the Life Insurance Companies of the United States covering a period of twenty-five years, show some remarkable results, as follows: More than twice as many users of liquor died of pneumonia as abstainers, the ratio being 18 to 39, and Dr. Osler states that "Alcohol is perhaps the most potent of all predisposing causes of pneumonia." The same is true of tuberculosis, the ratio here being 9.9 to 21.8: that is, for every 31.7 persons who died of the disease, 21.8 were drinkers, and only 9.9 were abstainers. Or to put it still another way, if you do not use alcohol, your chance of recovery is twice as good as though you drank.

Not only in special diseases but in general health, the insurance figures show the harm of alcohol. The lives of "light

drinkers" are shortened an average of four years, and that of "regular drinkers" six and a half years. In general, the death rate shows a margin of 26 per cent in favor of the non-user of alcohol. Not only is the life shortened, but the user of alcohol is ill 2.7 times as often as the abstainer, and his illnesses last 2.5 times as long; this causes not only discomfort but loss of work and money.

We have spent much time studying the prevention of typhoid fever and smallpox, and yet alcohol kills more people than typhoid and fifteen times as many as smallpox in this country every year. Perhaps the most awful item in this catalog of the effects of alcohol on the human organism is the fact that, throughout the United States, 26 per cent of the inmates of our insane hospitals owe their condition to the use of alcohol, either by themselves or their parents.

Mr. Arthur Hunter, the chief actuary of the New York Life Insurance Company, and President of the Actuaries Society of America, from whose reports many of these facts have been taken, sums up the case as follows:

"In my judgment, it has been proven, beyond peradventure of a doubt, that total abstinence is of value to humanity; it is certain that abstainers live longer than persons who use alcoholic beverages."

Still more recent data obtained by Dr. O. H. Rogers, Chief Medical Director of the same company, yield the following remarkable results: temperate regular users of alcoholic beverages show a death rate 18% higher than that of total abstainers; free users of alcohol, though not to the extent of drunkenness, showed a death rate 86% greater than in the case of non-users. Surely facts like these ought to deter any sane person from experimenting with such a dangerous drug.

Dr. Rogers concludes by saying, "there appears to be no limit within which alcohol may be entirely harmless. It is as if there were a direct relation between the amount of alcohol used and the amount of damage done to the body. The evidence is strong also that the damage persists a long time after drinking has been discontinued."

Alcohol is not a Medicine. In this connection it is well to remember that alcoholic beverages are no longer credited with any medicinal value, as shown by the following resolution, adopted by the American Medical Association, June, 1917:

"Whereas, we believe that the use of alcohol as a beverage is detrimental to the human economy; and

"Whereas, its use in therapeutics, as a tonic, or a stimulant, or a food, has no scientific basis; therefore be it

"Resolved, that the American Medical Association opposes the use of alcohol as a beverage; and be it further

"Resolved, that the use of alcohol as a therapeutic agent be discouraged."

The United States Pharmacopœia, the accepted guide book of medical preparations, was revised in 1917, and "whiskey" and "brandy" were struck out from its lists, which are supposed to contain all the useful drugs; "port wine" and "sherry" were left out several years ago. Dr. Harvey Wiley, perhaps the most celebrated food and drug chemist in this country, was chairman of the committee which made these changes. The present opinion of the best physicians is well voiced by Dr. J. N. Hurty, Secretary of the Indiana State Board of Health. He says, "Alcohol is opposed to the public health, for it hurts any animal organism into which it is taken. It is not a food; it does not aid digestion; it does not further the good of the body; on the contrary, it hurts."

Alcohol and Efficiency. Apart from its disastrous effect of health, the results of the use of liquor on actual ability to do work must be considered. The loss of labor due to alcohol-caused disease equaled the work of 150,000 men per year in the United States alone under unrestricted traffic. Sobriety will increase our total efficiency as a nation from ten to twenty per cent, adding to the country's wealth over two billion dollars besides what would have been spent for the liquor itself.

The people of the United States have added to our Constitution the 18th amendment, prohibiting the manufacture and sale of alcoholic beverages. If this is properly enforced, most of the awful results of the use of alcohol will disappear. It is to be

hoped that, in the future, a textbook will not have to contain a chapter on the evils of alcohol, any more than it would now on the evils of negro slavery.

The final outlawing of the liquor traffic can be attributed mainly to:

The long campaign of education as to its harm.

The economic waste of materials and labor.

The reduction in business efficiency.

The physical and moral effects.

Wood Alcohol. Although called alcohol, this substance is entirely different from grain alcohol which is found in beverages. It is even more dangerous, being a violent poison, especially harmful to the eyes and often producing incurable blindness. Unscrupulous dealers sometimes mix wood alcohol with grain alcohol in beverages and thus make them doubly dangerous. Wood alcohol is used for fuel and as a cleanser and should be handled carefully. It should not be rubbed on the skin and even the fumes are harmful to the eyes. It is also called methanol and has other trade names. Look at your labels and be careful in its use.

Effect of Narcotics on Cell Life. Alcohol is used as a killing and preserving agent for plant and animal specimens. Its action upon such organisms is readily studied.

Prepare two slides with active paramecia or other protozoa on each. Place them under separate microscopes. To one add a drop of 3% alcohol. Watch both for behavior of the protozoa.

On the slide to which alcohol was added, the motion of the paramecia will be speeded up for a few minutes, as compared with those on the other slide. However, the "stimulation" soon ceases and within ten minutes the animals are usually dead. Those on the check slide remain alive and active.

A tobacco solution can be made by blowing smoke through a little water, until it is colored light brown. If this solution is used on a paramecium slide, in place of the alcohol, the protozoa will gradually cease to move and eventually die.

Narcotics in general have a similar effect on cell life whether

in protozoa or man. The protoplasm of young organisms is more sensitive than that of adults. The use of narcotics, especially by young people, is distinctly dangerous.

Other Narcotic Drugs. Opium is prepared from the juice of the white poppy. From it are derived morphine, codein, and heroin, all of which are extremely dangerous narcotic drugs, even more injurious to their victims than alcohol. The habit is often formed by the use of these drugs or their compounds to relieve pain, sometimes by the advice of a physician. Like alcohol, their use creates a terrible craving for more and the grip of the habit is much harder to break. The results are also more serious. The victim suffers both physical and moral breakdown. Sleeplessness, difficult breathing, irregular heart action, and acute suffering especially in absence of the drug are accompanied by both mental and moral derangements which make the user entirely irresponsible for his actions.

Cocaine is another narcotic which is made from the leaves of the South American coca plant (no connection with the table beverage cocoa). It deadens sensibility to pain and is used in medicine and surgery. Its use is often continued or begun because of its soothing effects, but the habit once formed is as difficult to break as the use of opium, and the results are similar. The victim suffers loss of physical and moral control, often resorting to crime to obtain more of the deadly narcotic. The sale of both these substances is restricted to the medical profession and their use should be limited to imperative medical needs.

COLLATERAL READING

Alcohol and the Human Body, Horsely and Sturge, entire; *A Handbook of Health*, Hutchinson, pp. 93–103; *Physiologic Aspects of the Liquor Problem*, Billings; *The Human Mechanism*, Hough and Sedgwick, pp 366–376; *The Next Generation*, Jewett, pp. 118–125, 145–152; *Applied Physiology*, Overton, see index; *General Physiology*, Eddy, see index; *Principles of Health Control*, Walters, pp. 130–153 and index; *Civics and Health*, Allen, pp. 345–362; *Bulletins of the Scientific Temperance Federation*, Boston; "Alcoholism" in *Everybody's Magazine*, 1909; *The Great American Fraud*, American Medical Association, Chicago.

SUMMARY OF CHAPTER LV

ALCOHOL IN RELATION TO BIOLOGY

1. Introduction to study.
- a. Composition (C_2H_6O) ("ethyl" or "grain" alcohol).
- b. Character (narcotic poison).
- c. Reason for study here (its effect as a beverage).
- d. Kinds of alcoholic beverages.
  - (1) Beer.
    - (a) 2–5% alcohol.
    - (b) Made from malted barley.
  - (2) Wine.
    - (a) 15–20% alcohol.
    - (b) Made from fruit juices.
  - (3) Whiskey.
    - (a) 30–50% alcohol.
    - (b) Made from grains or fruits.
    - (c) Fermented and distilled.
- e. Proper uses of alcohol.

2. Alcohol not a food.
- a. Though oxidized, it produces a net loss of energy.
- b. Does not build tissue, but harms it.

3. Effect on nutrition.
- a. Makes food less digestible.
  - (1) Withdraws its water.
  - (2) Hardens its protein.
- b. Action on digestive organs.
  - (1) Irritates all membranes.
  - (2) Hardens tissue of the walls.
  - (3) Causes abnormal flow of fluids.
  - (4) Irritates and overworks the liver.

4. Effect on circulation.
- a. Interferes with nerve control of heart, etc.
- b. Relaxes arteries and capillaries.
  - (1) Strains heart.
- c. Blood driven to skin.
  - (1) Lowers temperature.
- d. Permanent inflammation of internal organs.
- e. Possible cause of disease.

5. Effect on respiration.
- a. Causes inflammation of mucous linings.
- b. Diminishes resistance to congestive diseases.

c. Increases connective tissue.
    (1) Lung action lessened.
d. Robs digested food of oxygen.

6. Effect on excretion.

a. Causes excess of uric acid.
b. Overtaxes the kidneys.
c. May cause disease (rheumatism, gout, Bright's disease, etc.).

7. Effect on nervous system.

a. Paralyzes higher centres first.
b. Later loss of bodily control.
c. Actual harm to nerve tissues.
d. Habit formation.
e. Insanity.

8. Alcohol and disease.

a. Diseases caused by alcohol.
    (1) Heart disease and heart enlargement.
    (2) Inflammation of liver and stomach.
    (3) Insanity.
    (4) Arteriosclerosis.
b. Lowers resistance.
    (1) Destruction of red corpuscles.
    (2) Predisposition to pneumonia, tuberculosis, etc.
    (3) Affects length of life, illness, etc.
c. Alcohol is not a medicine.

9. Effect of Narcotics on Cell Life.

10. Other Drug Habits.

CHAPTER LVI

SOME GENERAL BIOLOGIC PROCESSES

Vocabulary

Petrified, turned to stone.

We live in a balanced world. The constructive processes equal the destructive processes. Oxygen production equals oxygen consumption. Food materials come from soil and air and return to them again. Energy from the sun is used by plants, passed on to animals as food, and released by oxidation. Neither matter nor energy is destroyed; it is used over and over in the various cycles of nature. This is the law of conservation of matter and energy, which was referred to in a previous chapter.

Interdependence. Living things depend upon each other. Plants take water, mineral compounds, and carbon dioxide and, by the marvellous chemistry of their cells, build up their tissues, liberating oxygen meanwhile.

Animals use plant tissue for food and oxygen liberated by plants to set free its energy. They give back to the plant carbon dioxide in the air and the waste products of their bodies by way of the soil.

An Aquarium. This universal interdependence can be shown in a small way in a "balanced" aquarium or terrarium. If an aquarium is set up with a few green water plants rooted in gravel, and a few fish swimming in the water, a part of these nature circles can be observed.

The fish breathe the oxygen dissolved in the water and give off carbon dioxide which also dissolves. The green plants use the carbon dioxide in their food making and set free the oxgyen for the fish. No fresh water has to be added except to replace what evaporates. The oxygen-carbon dioxide balance is maintained.

In a small aquarium we have to feed the fish. In a state of nature they would be able to get their own food, either from the plants directly or from animals which feed upon the plants. Their waste products, on the other hand, would supply the mineral food materials for the plants, thus preserving the food balance.

A Terrarium. This same general relationship extends throughout nature. It is easier to see in an aquarium but can also be shown even in the laboratory by a balanced terrarium, though it is not so simple to maintain. In the terrarium cage we should have growing sod and plants, some common insects such as grasshoppers, and some small animals such as toads, turtles, or salamanders. There should also be a sufficient supply of moisture.

Here the same processes go on as we found in the aquarium. The plants supply oxygen and take up carbon dioxide. The insects eat the plants, the toads eat the insects, and both yield waste which goes into the soil for plant food. Insects and toads use in respiration the oxygen which the plants have provided and thus the circles are completed.

Don't forget that plants also use oxygen in their breathing but they liberate so much more than they use that the animals have an abundance. It is not easy to keep the balance perfect in a small cage, but in the world at large it is preserved, except where man has interfered.

Man's interference with nature's balance is shown in agriculture. We raise a crop of grain which takes food from the soil. In nature the plant tissue would decompose and return to the soil, or animals would eat it and return the waste matter of their bodies. Bacteria and oxidation would put these substances in shape for plant use and thus the balance would continue. However, we sell the crop and it is taken away; another is planted, and presently the soil food is depleted. The balance must be restored by manures or other fertilizers or else plants will no longer thrive.

Nature is full of examples of this intimate relation and interdependence. Man uses both plants and animals for food,

clothing, fuel, and shelter. He has been called a "parasite on the cow," and when we think of all the products which we obtain from this useful animal the expression seems to be justified. Without the milk, meat, and leather products which the cow provides, modern life could hardly exist.

Other interrelations are equally striking. Many plants could not reproduce without insects to pollinate them. Most insects could not live without plants upon which to feed. Earthworms get their living from the organic matter in the soil and at the same time keep the soil in condition for plant growth. Many bacteria live by decomposing organic matter, but this process is essential in replacing the food compounds in the soil, so that more organic life can be produced.

The balance is shown in another way. Any organism, if unchecked, would soon occupy the whole world. With no natural restrictions insects alone would sweep all plant life from the earth. Natural enemies in the form of birds, other insects, and parasites prevent this and a balance is reached where insect production is held in check by these forces of insect destruction.

If man interferes, either by destroying the natural checks, or by taking a species of insect out of the environment to which it has become adapted, it often multiplies to a serious extent.

The only remedy is to find the conditions which formerly held it in check and bring them into operation again. This is the explanation of the search for "natural enemies" which the government conducts, in hope of controlling imported insect pests.

Circles in Nature. It might seem, since food is oxidized or fuel is burned to release its energy, that the supply would be exhausted and all life come to an end. Nature, however, works in circles, reclaims all waste, and, aided by the sun, recombines them into useful compounds again.

The Carbon Circle. Carbon is one of the most necessary elements for all living things. Animals obtain it from plants and plants get it from the carbon dioxide of the air. Plants

take this carbon dioxide from the air, combine it with water from the soil, and lock up within the starch which is formed the energy of the sun which formed it.

However, the carbon is not lost. When either plant or animal, fire or decay, oxidize these plant products, carbon dioxide is set free again in the same amounts as before, mixes with the

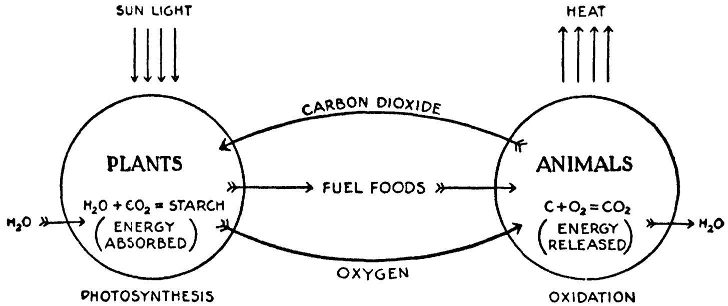


FIG. 200. Chart showing the interdependence of plants and animals for oxygen and carbon dioxide. This includes the "oxygen cycle" and the "carbon dioxide cycle."

atmosphere, and is ready for plant use again. No atom of carbon has ever been destroyed or produced by life processes; it is merely used over and over again.

The Oxygen Circle. Oxygen is equally important, both as being a part of all living tissue, and as the liberator of vital energy. It is taken from the air whenever plants or animals breathe, or wherever fire burns or substances decay.

All these processes combine the oxygen into carbon dioxide, water, or other oxides, and one might suppose that it was permanently removed from circulation, but this is not the case. Plants take this carbon dioxide and water, unite them to form starch, set oxygen free in the air again, and thus this circle is completed. A study of the diagrams will help to fix this in your mind.

Nitrogen Circle. Nitrogen, also, is absolutely essential to all living tissue and protoplasm as well as to all protein food. Plants obtain nitrogen compounds from the soil, mainly as soluble nitrates. They use them in making their living tissues,

which in turn furnish to animals their only source of nitrogenous food.

Here again one would be justified in supposing that the nitrogen was out of reach of future use. If this were so, life would long since have ceased, as ordinary soil contains only enough nitrogen compounds to last about seventy years, if none were replaced.

All waste excreted from animals contains nitrogen compounds, and in the course of nature this should get back to the soil as natural manures. Whenever a plant or animal dies, decay takes place, and much of its nitrogen is thus returned by the action of certain decay bacteria. However, neither manures nor decay would give back enough, especially as man removes his crops and disposes of all his sewage by washing it into rivers or ocean where their nitrogen cannot get back to the soil from which it came.

Furthermore, much nitrogen is set free into the air by decay and oxidation in such a way that plants cannot use it, except it be combined with other elements. So there would be a serious shortage if it were not for other means of return. It remains for certain bacteria, living in the nodules which they form on the roots of clover, peas, beans, alfalfa, and all members of this large family of plants, to aid in making good the loss.

These bacteria take the free nitrogen from the air, combine it into soluble compounds, and thus replace in the soil most of this essential element, which decay and oxidation had set free in the air. Although the atmosphere contains an enormous amount (80 per cent) of nitrogen, it is not in the form of compounds, and these plants of the pea family are important because they help to put this nitrogen into usable form.

Another means by which free nitrogen of the air is combined into useful compounds is by the action of lightning, which converts some into oxides. These are washed back to the soil by rain and help in completing the circle.

In addition to these natural steps in the nitrogen circle we must remember that man has learned to use the energy of nitrogen compounds in all his explosives and many other chemi-

cals. This interferes seriously with nature's plan, for the firing of one twelve-inch gun wastes nitrogen enough to raise one hundred bushels of wheat. To repair this loss we are just learning to combine the nitrogen of the air artificially into useful compounds, and replace them in the soil as fertilizers. Unless this is done, the end of the nitrogen supply is in sight, due, as

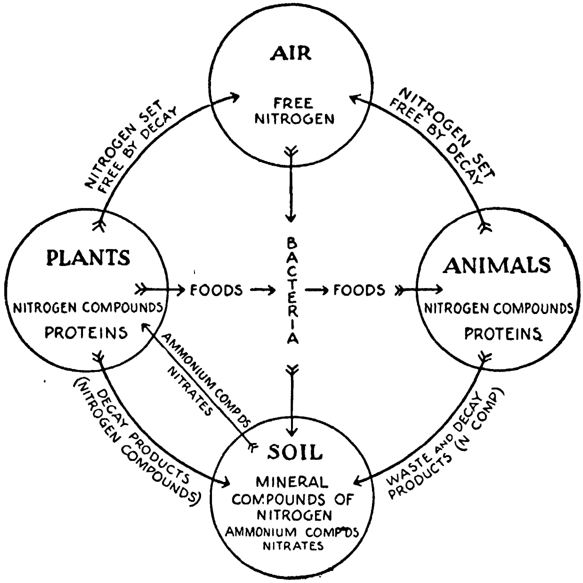


FIG. 201. Diagram showing how nitrogen compounds, after being used by plants and animals are either returned to the soil by decay or are reclaimed from the air. This is the "nitrogen cycle."

usual, to man's interference in nature's processes. He wastes nitrogen as sewage, chemicals, and explosives, so must do his part in completing the circle or suffer the consequences.

NITROGEN IN THE SOIL

Removed by	*Replaced by*
Life processes	Manures
Decay (some kinds)	Decay
Oxidation of useful forms	Bacteria
Waste of sewage	Electrical action
Industrial uses	Artificial processes
Explosives	Fertilizers

Other Elements. The circles which are followed by the other elements found in plant and animal tissue are not so complicated. Hydrogen comes and goes as water, of which there is a limitless supply in most regions. The sulphur, phosphorus, potassium, and other mineral compounds are usually abundant to begin with, and are not set free by decay, but come back to the soil in usable form.

If a soil becomes deficient in any of these, they are obtained elsewhere as natural mineral deposits and replaced as artificial fertilizer. In a state of nature this would never be necessary, as the plants would die and decay where they grew and so return their mineral salts to the soil that produced them. It is only when man removes his crops and uses them elsewhere, that artificial replacement is necessary.

Oxidation and Life. In the process of photosynthesis, green plants accomplish the manufacture of organic food and tissue out of inorganic materials, carbon dioxide, water, and mineral salts. They are able to do this because, by means of their chlorophyll, they can absorb energy from the sunlight sufficient to unite these inorganic materials into complex organic substances.

Animals cannot thus manufacture their own food, as they do not possess chlorophyll. It is evident that they must depend upon plants for organic food substances. Of course there are animals which eat no plant foods, but they depend upon animals which do, so that in the end plants are the only food producers.

The chief function of food is to provide energy to support the life of the consumer. This energy came from the sun, was locked up in the food substance by photosynthesis, and has to be released by oxidation or some similar process.[1] Hence

[1] Throughout this book we have spoken of oxidation as the source of bodily energy and heat. Recent investigations seem to modify this view. Muscular energy appears to come from a more complicated series of chemical changes in the muscles, in which glycogen, glucose, or some similar digested sugar, is changed into lactic acid. This liberates ample energy for the activity of the body.

Oxidation is still necessary to remove part of the lactic acid by converting it into carbon dioxide and water in the usual oxidation reaction. This partial oxidation appears to change the remaining lactic acid back into

the importance of oxidation as the key which unlocks the storehouses of solar energy, and makes it available to support life. We do not know how the energy, thus released, produces what we call "life," but we do know, that without it, no life exists and that, when oxidation ceases, life ceases too.

Other Sources of Energy. Outside of living energy there are two other general sources which man has learned to use, the power derived from fire and that obtained from water. In the case of heat energy we burn (oxidize) various fuels such as wood, coal, gas, or oil. All these fuels are originally derived from plant life. The energy which we set free from them, therefore, came originally from the sun. Someone has called coal "petrified sunshine"; this is almost true. When we warm our hands at the open grate, or heat our house with coal, or cook with gas, or light our rooms with electricity, we are setting free in various forms the energy absorbed from the sun by plants.

But suppose the mill is run or the electricity used is generated by water power. Here again the sun is the final source because its heat has evaporated the water, which has risen as clouds, fallen on the hills as rain, and, flowing down again to the sea, turns the water wheels. To be sure there is no oxidation involved in this process, but it shows how the sun, either by its light or its heat, is the source of all our energy, both living and mechanical.

Osmosis and Life. The life of any organism depends first, upon getting food into its tissues, and second, upon releasing the energy from the food after it has assimilated it. These food-obtaining processes include photosynthesis, digestion, absorption, and assimilation. All these depend upon osmosis for their accomplishment.

After the food is available in the body, its energy must be released. This requires oxidation and again necessitates osmosis

glycogen again, which can be used over by the muscles. This is the modern view of the function of oxidation in the muscles.

If oxygen be lacking, lactic acid accumulates and produces "fatigue," which stops muscular action unless it is removed by oxidation. It is thus apparent that oxidation is essential to muscle action, but in a different way from that which was formerly supposed.

for the passage of oxygen through the tissues. Oxidation liberates the energy in the food and at the same time produces waste which must be excreted. Here again osmosis is the essential process.

The tables which follow attempt to show this relation of osmosis to the vital processes of all plants and animals. The arrows indicate the direction of the osmotic flow. The vertical line represents the cell wall or membrane with its protoplasmic lining which makes up the semi-permeable osmotic membrane. The fluids of different densities are placed in the two columns.

Osmotic Processes in Plants

Absorption

Soil water	Root hairs	Cell sap
Water →		→
Mineral salts →		→

Photosynthesis

Air	Spongy parenchyma	Chlorophyll-bearing cells
Carbon dioxide →		→
←		Oxygen
Sap		
Water →		→
←		Starch products

Transpiration

Sap	Leaf cells	Air spaces
Excess water →		→

Transportation

Sap	Stem and root cells	Sap
Food stuffs →		→ via ducts, bast, etc. (successive osmosis)

Digestion

Food in seed or root	Seed or root cells	Embryo or growing plant
Soluble foods →		→

Osmotic Processes in Animals

Respiration

Air in lungs	Walls of lung cell and capillaries	Blood
Oxygen →		→
←		Carbon dioxide
←		Water vapor
←		Nitrogenous waste

Digestion

Food in digestive tract made soluble by ferments	Cell walls of digestive organs and capillaries	Blood
Peptones →		→
Sugars →		→
Fats as acids →		→
as emulsions →		→

Assimilation

Blood and lymph	Cell wall of capillaries and tissues	Tissues
Oxygen →		→ (Used for release of energy)
Peptones, sugars, etc. →		→

Excretion

Urine and perspiration	Cell walls of kidney and skin capillaries	Blood in kidneys and skin
←		Carbon dioxide
←		Water (liquid)
←		Nitrogenous wastes
←		Urea, etc.

Evolution of Life Functions. Biology teaches that all living things are alike in their fundamental life processes, that all forms are related by descent from common ancestors; that as development proceeds, they become better fitted to perform their life functions, or in other words, become more highly specialized.

The accompanying tables are intended to summarize this development in life processes, as shown in the forms which we have studied. It is necessarily much condensed, but careful study will reveal many of the facts brought out during the course.

EVOLUTION OF LIFE FUNCTIONS (PLANTS)

Organism	Food-Getting	Digestion and Assimilation	Respiration	Excretion	Reproduction	Motion and Sensation
Spore plants, bacteria and yeast	No chlorophyll, parasitic or saprophitic	By protoplasm direct	Oxygen from water through cell wall, for heat and energy	Through vacuoles and cell wall	"Multiplication by division"	Very little, or no motion or sensation
Seed plants						
1. Germinated seed	Food stored by parent in endosperm or cotyledons	Digestion by diastase, protoplasm assimilates	Cells take in oxygen, produces life energy	Transpiration in leaf and stem	Cell division for growth only	Heliotropism, hydrotropism, geotropism
2. Adult plant	Leaves, CO_2 and H_2O united by light Starch and N, S, P, make proteins	Each cell makes diastase, circulation, protoplasm assimilates Plants use more food for *growth;* animals use more for *energy*	Oxygen from air, via stomates and lenticels and intercellular spaces	CO_2 and H_2O through air spaces, stomates, and lenticels Wastes in fall of leaves	Cell division for growth New plants by fertilization Sperm + ovule form embryo and food (seed)	Plants move by growth of tissues Animals move by contraction of tissue

Plants reached height of development of development in composites
Further evolution hindered by lack of sensation and motion

Evolution of Life Functions (Animals)

Organism	Food-getting	Digestion	Respiration	Excretion	Reproduction	Motion and Sensation
Protozoa, paramecium	Cilia, via gullet	By protoplasm direct	Dissolved oxygen from water through cell walls	Through vacuoles and cell wall	"Multiplication by division"	Pressure sensation Motion by cilia
Crayfish	Claws, maxillipeds, maxillæ, mandibles to mouth	Systems of organs for digestion, circulation, etc. Protoplasm assimilation	Gills, under carapace take oxygen from water. Gill bailer causes fresh flow	CO_2 by gills: waste from green gland	Cell division for growth. Fertilized eggs held on swimmerets	Sight, smell, touch, various motions of appendages, swimming and walking
Grasshopper	Maxillæ, lips and mandibles; aided by sight and locomotion	As above	Tracheæ take oxygen from air. Blood loose in body. Oxidation in cells	CO_2 by spiracles. Urea by excretory tubes on intestine	Internal fertilization, eggs buried by ovipositor	All "senses." High instinct Rapid motion by legs, wings, etc.
Fish	Teeth and mouth for prehension; aided by senses, and locomotion	As above	Oxygen from water through gill walls. Oxidation in cells	CO_2 by gills Urea by kidneys	Eggs externally fertilized, little parental care	All "senses" somewhat: lateral line for pressure, motion by fins, tail, etc., muscles in layers
Frog	Tongue, mouth, and teeth; aided by senses and locomotion	Mouth, saliva (starch). Gullet, mucous. Stomach, gastric (proteid). Intestines, bile (fats), pancreatic. All food absorbed by villi carried by plasma. Assimilation by protoplasm	Oxygen from water through skin Oxygen from air through lungs Air "swallowed," carried to cells by red corpuscles. Oxidation in tissues	CO_2 from lungs Other wastes from kidneys	Eggs externally fertilized, in masses, metamorphosis. Tadpole to frog	Usual senses, spindle-shaped muscles, arms and legs; latter long and webbed. Land or water travel
Man	Essentially same as the frog; better coördination; success achieved in one line; that is, development of sensation toward *reason*					

COLLATERAL READING

Osmosis: *Fundamentals of Botany*, Gager, pp. 54–60; *The Living Plant* Ganong, pp. 165–179; *Principles of Botany*, Bergen and Davis, pp. 36–39; *Introduction to Botany*, Stevens, pp. 35–39; *Plant Physiology*, Duggar, pp. 64–83; *Textbook of Botany*, Coulter, Vol. I, pp. 302–309; *Applied Biology*, Bigelow, pp. 85–97; *The Science of Plant Life*, Transeau, pp. 166–178; *General Physiology*, Eddy, pp. 136–142; *College Botany*, Atkinson, pp. 13–21.

SUMMARY OF CHAPTER LVI

SOME GENERAL BIOLOGIC PROCESSES

1. The Balance of Nature.
- a. The balanced aquarium.
- b. The balanced terrarium.

2. Interdependence.
- a. Plant and animal.
- b. Man and other living things.
- c. Insects and plants.
- d. Insects and their enemies.

3. Circles in Nature.
- a. The carbon circle.
- b. The oxygen circle.
- c. The nitrogen circle.
- d. Other elements.

4. Oxidation in Living Things.

5. Osmosis in Life Processes.

6. Evolution of Life Functions.

CHAPTER LVII

THE HISTORICAL DEVELOPMENT OF BIOLOGY

Vocabulary

Spontaneous, without cause.
Mortality, death rate.
Enumerate, to make a list of, to number.
Rabies or hydrophobia, the disease caused by mad dog bite.
Virulence, disease producing ability.

Like all other sciences, biology has developed from small beginnings by the labor, study, and sacrifice of many men over a long period of years. Biology might be said to have started when man first became intelligent enough to observe the plants and animals with which he was surrounded, and utilize or avoid them as he found best.

Hard Won Knowledge

Circulation. We gain our present knowledge so easily and take it so much for granted that we can hardly realize the struggles by which even our simplest facts were obtained.

Every child knows that the blood circulates in the arteries, but the ancients believed that they were air tubes and it was only in 1628, after much opposition, that Harvey was able to prove fully this fact of circulation.

Spontaneous Generation. We assume, as a matter of course, that any plant or animal springs from a parent like itself, but up to 1668 it was believed that maggots came from decayed meat, that frogs came from mud, and that living things were produced from non-living matter. At that date Redi discovered flies' eggs and larvæ and proved that the maggots were produced by flies. The presence of bacteria in decaying substances was not explained until 1850–70.

At that time Pasteur and Tyndall showed that bacteria would not develop except when the medium had been exposed,

and so proved, even for these minute plants, that bacteria were produced by bacteria, and in no other way.

The idea that life could come from dead matter was called the theory of "spontaneous generation," and died hard. This is now replaced by the belief that "all life comes from life."

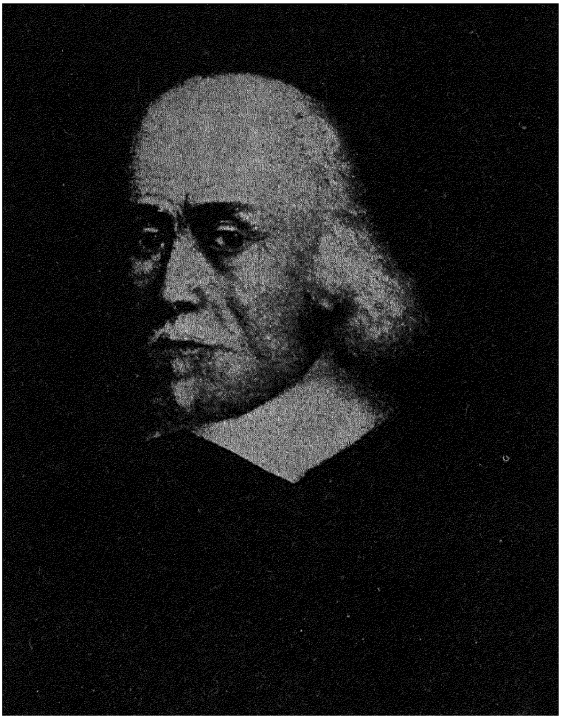


FIG. 202. William Harvey. 1578–1667.

Oxidation. We talk freely of oxygen and oxidation, but oxygen was not discovered until 1774 when Priestley obtained it and demonstrated some of its properties. Even then scientists believed that when a substance burned it gave off something instead of combining with something (oxygen) as we now know to be the case.

Vaccination. All of us are vaccinated and think nothing of it, but before 1796 smallpox raged unchecked and was so common that about 95 per cent of all people had it. We little realize the struggle of Dr. Edward Jenner, an English physician, who was the first to suggest vaccination as a means of prevention.

He observed that the dairy maids who had had cowpox (a mild form of smallpox) did not fall prey to the latter disease. Reasoning from this he proposed to inoculate people with cowpox as a protective measure, and suffered ridicule, opposition, and persecution before he could convince the public. Even now there are a few misguided individuals who oppose vaccination, even though its practice has made smallpox an uncommon disease.

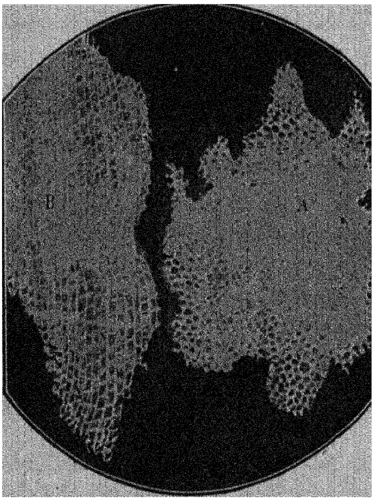
Development of Biology

It would be impossible to enumerate here all the famous names in biology or to sketch their contributions to our knowledge. Only a few can be mentioned, but there are books, like *Biology and Its Makers* by Locy, which deal with the subject in fascinating style and treat of all the most important discoverers.

A few of these are listed in the tabulation at the end of this chapter, and a glance at it will show two things,—how old some of our biologic ideas are, and how young is our definite knowledge sufficient to apply them. The Greeks theorized vaguely about evolution and development, but it was over two thousand years before Darwin and others proved it. Galen was the foremost physician of his time, but modern medicine scarcely had its beginnings till fifteen hundred years later.

Cells and Protoplasm. Hooke saw cell walls in cork bark in 1665, but it was nearly two hundred years before the importance of the cell as a unit of tissue structure was proven by Schleiden and Schwann in 1838–39. Both Schleiden and Schwann noticed the jelly-like substance in the cells but it was not until 1846 that von Mohl called it "protoplasm" and fifteen years later, 1861, Schultze showed that it was the fundamental material of both plants and animals.

Louis Pasteur. Probably no one has applied biology to benefit mankind to a greater degree than Louis Pasteur, born in France in 1822: died 1895, "the most perfect man in the realm of science." In 1857 he showed the relation of bacteria to fermentation and greatly benefited the wine industry of France by his investigations. In 1865–68 a disease attacked the silkworms of France and Italy and threatened to wipe out the industry. Pasteur traced this to bacterial attack, and was able to suggest means by which the silk business was saved.



From Locy.

FIG. 203. The earliest known picture of cells from Hooke's *Micrographia* (1665). Edition of 1780.

Later his attention was turned to chicken cholera and other animal diseases and from his researches along these lines he developed the treatment by inoculation, and laid the foundation for all modern serum and anti-toxin treatments.

His most famous work was done in the treatment of rabies. This consists in injecting weak doses of the hydrophobia germs into the blood of a person bitten by a mad dog. By gradually increasing the virulence of the injections anti-toxins are built up in the patient's body and resist the real attack of the disease. By this treatment the mortality has been decreased from practically certain death to less than one per cent.

The world owes to Pasteur the foundation of all our modern methods in bacteriology, our serum and anti-toxin treatments, and all the lives that have been saved thereby. Possibly more people owe their lives to the results of his work than to that of any other man who ever lived.

Other Victories over Disease. At the Pasteur Institute many discoveries have been made in the line of inoculation against lockjaw (tetanus), bubonic plague, and other germ diseases, but none has saved more lives than the antitoxin for diphtheria. This was developed by Roux, a fellow-worker with Pasteur, and by von Behring, a German bacteriologist, in 1894. By this use a disease which annually caused the death of thousands of children now has its rate reduced about 80 per cent, and if treatment is given early in the case, recovery is almost certain.

The toxin-antitoxin treatment is a recent development by which diphtheria can be *prevented* by making the patient immune to its attack.

Among others who have labored in the work against germ disease may be mentioned Robert Koch, who studied the relation of bacteria to human disease, especially in the case of tuberculosis and Asiatic cholera. He was the first to identify these bacteria and though he devoted his life to the work, did not discover a specific cure for tuberculosis. However, his work has enabled us to take preventive measures which are greatly aiding in suppression of this worst of the "ills that flesh is heir to."

Antiseptic and Aseptic Surgery. Sir Joseph Lister, an English surgeon, was the first to fight the germs of the operating room by the use of antiseptics, such as carbolic acid. This one discovery has done more to prevent death by infection after operations than any other of recent times. Modern surgery aims to keep its wounds *aseptic*, that is, free from all germs by careful methods of sterilization, but still relies on *anti-septics* to kill any germs that may have found entrance. Before Lister's time infection of operative wounds was to be expected—now it would be considered evidence of gross carelessness and very rarely occurs.

Among other names to be associated with modern advance against disease is that of Paul Ehrlich. He is famous for his study of the blood as related to immunity to certain diseases, and especially because of his successful method of treating syphilis, which before had been incurable.

Another scientist who worked along similar lines was the

Russian, Metchnikoff, who was the first to discover the functions of the white corpuscles in combating disease germs in the blood.

Carrell and Flexner are two American scientists who are working at the present time to carry the fight against disease to a more successful conclusion. Among many other discoveries, Carrell has developed a very successful method of treating infected wounds which saved thousands of lives during the

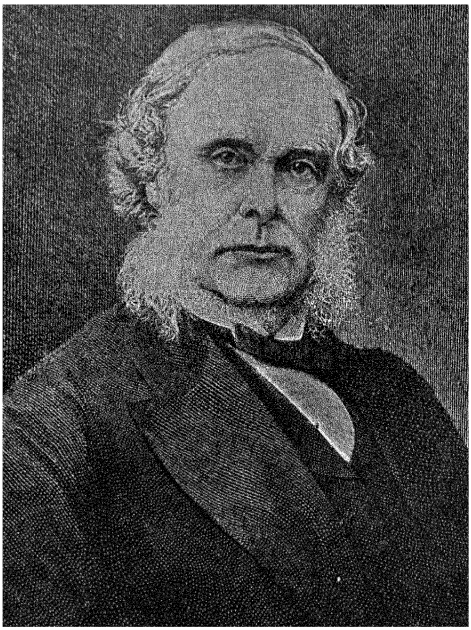


FIG. 204. Sir Joseph Lister. 1827–1912.

war. Flexner has been investigating anti-toxin treatments for infantile paralysis and similar diseases.

Charles Darwin. If applied biology owes its greatest debt to Pasteur and his successors, certainly theoretical biology owes more to Charles Darwin and his co-workers than to any other man. His work along the line of evolution and natural selection

revolutionized all modern thought and has been briefly described in Chapters XXXV and XXXVI.

Associated with him was Alfred Russel Wallace, who reached the same conclusions as Darwin, though working from different facts and entirely independent of his ideas.

Huxley, another English scientist, defended and explained Darwin's theories, and Herbert Spencer, also English, applied

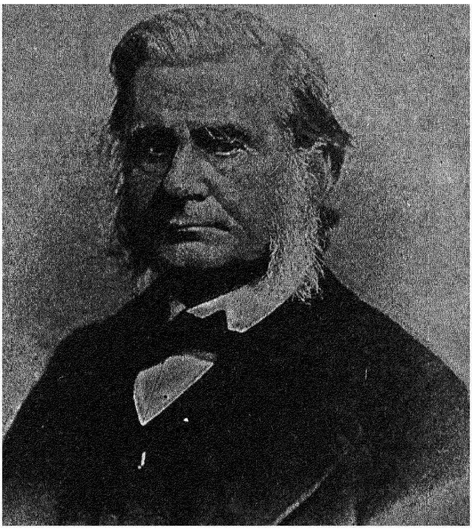


FIG. 205. Thomas Henry Huxley. 1825–1895.

them to all lines of scientific thought. Upon the foundation laid by these men, all modern biology is based.

Mendel's Law of Inheritance. In 1860 an Austrian priest by the name of Gregor Mendel began raising peas in his garden at Brünn. He was not so much interested in the flowers or the abundance of the crop as in other apparently less important matters.

He noted the shape of seeds and their color, the shape and color of the pods, the height of the plant and other similar

characteristics. He kept each kind separate and cross-pollinated them himself, so knew exactly the ancestry of each new set of descendants. After several years of patient experiment and careful record he reached some conclusions. He found that if he crossed tall with short that the next generation were hybrids

FIG. 206. Gregor Mendel. 1822–1884. Permission of Professor Bateson.

but tall in appearance,—that is, tallness had overcome shortness as a characteristic in that generation.

Many characteristics were found to be stronger at first and were called "dominant" characteristics. Those which were crowded out were called "recessive." However when these hybrids were bred together both the original characteristics reappeared in a constant proportion of tall, short, and tall hybrids.

The reason is that the two characteristics remained *separate* in the hybrids and did not blend, hence when hybrid was bred

with hybrid the next generation would combine these characteristics according to the mathematical law of probabilities or chance.

To illustrate, let x and y stand for any two non-blending characteristics. The first crossing would produce hybrid offspring having xy characteristics, but if x were dominant, y would not appear.

However if these xy hybrids are crossed together, four possible combinations may occur, thus:

Joining	x	with	x	producing	xx	offspring.
"	x	"	y	"	xy	"
"	y	"	x	"	yx	"
"	y	"	y	"	yy	"

$$
\begin{array}{ccl}
x & y & \text{........hybrid} \\
\\
x & y & \text{........hybrid} \\
\hline
xx & xy & \\
 & yx & yy \\
\hline
xx & 2xy & yy
\end{array}
$$

Of course the xy and yx individuals are of the same kind and are also like their xy hybrid parents, but the xx and yy offspring have those characteristics *only* and are pure bred: their offspring with either x or y respectively would produce pure x or pure y characteristics, despite their mixed ancestry.

Of course breeding is not so simple as this, because it cannot be limited to one characteristic at a time, and some characteristics do blend or average in the hybrids, but the law of inheritance, known as Mendel's Law, has been proven true and is of great value in plant and animal breeding.

Though Mendel published his conclusions in 1865, little notice was taken of them, and he died in 1884 without recognition. Later the same conclusions were independently reached by three other scientists who would have been credited with an important discovery, but in 1900 Mendel's papers were found, and his long delayed appreciation arrived sixteen years after his death.

Briefly stated, his law comprises three facts:

1. Pure bred mated with pure bred of *same* kind give offspring pure bred.

2. Pure bred mated with pure bred of *different* kind,—hybrid offspring.

3. Hybrid mated with hybrid the offspring will be one-half hybrid, one-quarter pure bred like grandfather, one-quarter pure bred like grandmother.

Sir Francis Galton. Another important contributor to our knowledge of inheritance was a cousin of Charles Darwin, Sir Francis Galton. He developed the idea of heredity, especially as applied to man's inheritance of good or bad qualities. To this branch of biology he gave the name *eugenics,* which means the science of being well born.

Knowledge of eugenics is rapidly increasing and it is now known that certain characteristics of body and mind are definitely inherited. The race can be protected from degeneration by preventing defective persons from marrying and thus continuing their bad inheritance. Laws are now in effect in many places which help to regulate these matters by forbidding marriage of defectives and by requiring a mental and physical examination before issuing a marriage license.

Galton and others collected statistics as to the family histories of good and bad inheritance; the results are remarkable. Some of the well known examples are as follows. Jonathan Edwards was a distinguished New England preacher. He was President of Princeton University and a fine, upright, intellectual man. His descendants in the year 1900 numbered 1300 persons. Among this number were over 100 clergymen, about the same number of lawyers, 295 college graduates, 65 college professors, and 13 college presidents. There were 60 doctors, 60 prominent authors, 75 military officers, 80 public officials, and 30 judges. Among this notable list was one vice-president, several senators, governors, foreign ministers, and eminent business men. So far as is known, no member of the whole six generations was ever convicted of crime.

Many such examples have been traced through varying lengths

of time. Such are the Lee family of soldiers, the Hutchinson family of musicians, and the Lowells, noted for literary ability.

Example of opposite types of heredity are, unfortunately, not rare. In the notorious Jukes family, six generations, numbering 1200 persons, included the following: 7 murderers, 130 convicted criminals, 60 thieves, 310 professional paupers, and 440 immoral or syphilitic persons. Every grade of viciousness and idiocy was represented in the descendants.

People often take pride in tracing their ancestry to some "noble" family of European aristocracy and rejoice to find a coat of arms on their family tree, regardless of the character of the ancestors who bore it. How much greater pride one ought to take in ancestry of clean, healthy bodies and well disciplined minds from which to trace one's descent.

This implies a heavy responsibility on the present generation, first, to acquire such characteristics as will be worth transmitting, and secondly, to use the greatest care in selection of friends, from whom the prospective husband or wife is likely to be chosen.

Luther Burbank. Practical biology as applied to cross-breeding and selection of plants has been developed by Luther Burbank. For years he has been performing what might be called biologic miracles on his farm in California.

A complete list of the new or improved plants which he has developed would occupy a whole chapter, but some of the most famous are:

1. The Burbank potato, which has increased our crop by millions of dollars and is said to have prevented the potato famine that formerly devastated Ireland.
2. The spineless cactus, which provides abundant stock food for regions where none was to be had.
3. The "Primus Berry," a valuable cross between the dewberry and raspberry. It differs from both its ancestors and is the first absolutely new species ever produced by man.
4. A cross between the plum and apricot called the "Plumcot," which has the good qualities of both ancestors and some of its own.
5. The pitless plum and thin-shelled walnut explain themselves.

6. Among flowers, the Shasta daisy six inches in diameter and the ten-inch poppy, are well known.

He works by cross-pollination, grafting, and rigid selection. Specimens are collected from all over the world, raised in his gardens, and crossed to develop desirable characteristics. They are then cultivated in enormous numbers, to take advantage of all possible variations, and only the best are selected.

Thus, by combining knowledge of biologic laws with marvellous skill in their use, Mr. Burbank has developed plant breeding to a degree never approached before.

John James Audubon. Audubon represents a different type of biologist. His fame rests upon his studies and pictures of American birds. He was born in Louisiana in 1781, studied art in Paris, and returned to this country in 1800. He spent fifteen years exploring the forests of North America, painting pictures of the birds and studying their habits.

Often he worked under great difficulties and sometimes paid his way by painting portraits. His *Birds of America* consists of four wonderful volumes of bird pictures numbering 1065, all in natural size and color. The work took ten years of labor and cost $100,000 to publish, but has been called "the most magnificent work of its kind ever published."

Audubon died in 1851, but his name has come down to us, associated with bird study. It is now made familiar through the National Association of "Audubon Societies," whose work is the study and protection of the birds which Audubon so loved to paint.

COLLATERAL READING

Encyclopedia references on all persons and topics mentioned. *Biology and its Makers*, Locy, entire; *Main Currents of Zoölogy*, Locy, entire; *Elementary Biology*, Peabody and Hunt (Malaria), pp. 47–56, Pt. I; *Life of Pasteur*, Frankland; *Children's Stories of Great Scientists*, Wright; *General Zoölogy*, Linville and Kelly, pp. 436–451; *Zoölogy*, Parker and Haswell, pp. 628–649; *General Principles of Zoölogy*, Hertwig, pp. 7–67; *General Zoölogy*, Pearse, pp. 6–12; *Manual of Zoölogy*, Hertwig-Kingsley, pp. 7–56; *Biology*, Calkins, pp. 219–232 (Mendelism); *Mechanism of Mendelian Heredity*, Morgan, etc., entire; *The Next Generation*, Jewett, pp. 20–24 (Mendelism).

New Biology, Smallwood, pp. 649–670; *Biology of Man and Other Organisms*, Linville, pp. 450–478; *Practical Zoölogy*, Hegner, pp. 472–481.

Biology's Pioneers

Name	Date	Nationality	Contribution to Biology
Heraclitus	500 B. C.	Greek	Theorized vaguely on the idea of evolution
Empedocles	450 B. C.	Greek	Suggested natural selection and survival of the fittest
Aristotle	350 B. C.	Greek	Founder of zoölogy. Emphasized importance of observation Long considered very high authority
Pliny	79 A. D.	Roman	Wrote first popular book on "Natural History"
Galen	169 A. D.	Greek	Founder of ancient medical science and physiology
Vesalius	1542	Belgian	Founder of modern anatomy and human dissection
Harvey	1603	English	Worked out circulation of the blood. Studied embryology
Malpighi	1661	Italian	Discovered capillaries in the lungs Described development of chick embryo
Leeuwenhoek	1667	Dutch	Invented microscope (?) Saw bacteria but did not understand them
Redi	1668	Italian	Disapproved spontaneous generation. Wrote on insects' life histories
Hooke	1665	English	Discovered cell walls in cork bark Worked out microscopic structure of some plants
Borelli	1680	Italian	Discovered function of muscles, acting with bones as levers
Hales	1727	English	Discovered plant respiration
Linnæus	1753	Swedish	Devised modern method of plant classification and naming
Priestley	1774	English	Discovered oxygen; studied plant respiration
Jenner	1796	English	Discovered vaccination
Sprengel	1796	German	Studied fertilization and insect pollination
Lamarck	1801	French	Invented a scheme of animal evolution based on inheritance of acquired characteristics. Not now accepted First to use term "Biology"
Audubon	1820	American	Notable bird student and artist
Schleiden	1838	German	Regarded cell as unit of plant structure. (Founded "cell theory")

BIOLOGY'S PIONEERS.—*Continued*

Name	Date	Nationality	Contribution to Biology
Schwann	1839	German	Discovered cell as unit of animal structure. (Founded "cell theory") Worked with Schleiden
Agassiz	1840	Swiss	Wonderful teacher of zoölogy, Harvard
Mohl and Schultze	1846 1860	German German	Studied and named protoplasm
Pasteur	1857	French	Studied bacteria in relation to fermentation and disease of plants and animals. Developed use of serums and antitoxins
Darwin	1859	English	Explained evolution by natural selection Wrote *Origin of Species*
A. R. Wallace	1859	English	Reported work similar to Darwin's based on geographic distribution
Huxley	1863	English	Defended and explained Darwin's theory Developed "laboratory method" of teaching
H. Spencer	1865	English	Applied evolution to all sciences Originated expression "survival of the fittest"
Mendel	1865	Austrian	Discovered law of heredity
Lister	1867	English	Developed antiseptic surgery
Ehrlich	1875	German	Studied blood composition. Discovered cure for syphilis
Metchnikoff	1875	Russian	Discovered white corpuscles and their functions
Koch	1880	German	Proved relation of bacteria to human disease Discovered germs of tuberculosis and Asiatic cholera
Laveran	1880		Discovered malarial parasite in mosquito
Roux and Behring	1894	French and German	Antitoxin treatment for diphtheria
Reed, Lazear	1898	American	Discovered relation between mosquito and yellow fever
Howard	1898	American	Discovered relation between fly and typhoid
Burbank	1900	American	Applied modern biology to plant breeding
Carrell	1906	American	Developed methods of wound antisepsis, later used in war
Flexner	1910	American	Developed modern serum and antitoxin treatment

APPENDIX

SELECT LIST OF REFERENCE BOOKS

Where only a few books can be had for collateral reading, the following will be found as helpful as any in their respective fields. References to these are included in the lists at the end of each chapter.

Practical Zoölogy, Hegner,	Macmillan.
Fundamentals of Botany, Gager,	Blakiston.
Applied Biology, Bigelow,	Macmillan.
Animal Life, Jordan & Kellogg,	Appleton.
American Natural History, Hornaday,	Scribners.
Our Vanishing Wild Life, Hornaday,	"
Plants and their Uses, Sargent,	Henry Holt and Co.
Flower Guide, Reed,	Doubleday Page & Co.
Bird Guide, Part 2, Reed,	" " "
Insect Life, Comstock,	Appleton.
Human Mechanism, Hough,	Ginn & Co.
Principles of Health Control, Walters,	Heath.
Our Native Trees, Keeler,	Scribners.
Primer of Evolution, Clodd,	Longmans, Green & Co.

Much valuable material can be had free or for small cost from the various government and private departments, bureaus, and organizations which are mentioned in the text and in the lists of collateral readings. Have your school put on the mailing lists of the Federal and State Departments of Agriculture, Forestry, Biological Survey, and related departments.

When requesting literature, use your school letterhead and state that the material is to be used for school purposes; the results are usually gratifying and helpful.

Characteristics of a Few Common Birds

In this comparison, the size of the robin is taken as a standard and is called 10. The other birds are referred to this number, for instance the bluebird is marked "7" which means that it is $^7/_{10}$ as large as a robin. Those marked "resident" remain through the whole year, in most parts of the country.

Consult bird books for full descriptions.

Name and size	Color	Habitat	Food
Flicker (13)	Brown with black stripes above. Yellow under tail and wings. Red back of head. Black crescent on breast	Woods, orchards. Digs nest hole in trees	Grubs, ants, insects. Wild fruit
Downy Woodpecker (6)	Black and white striped Red on top of head.	Open woods. Orchards. Resident	Larvæ of borer. Grubs. Insects
Phœbe (7)	Gray-brown above. Yellowish-white below. White wing bars	Shade trees. Nests on barns and bridges	Insects
Crow (19)	Black	Woods and fields. Resident in colonies	Insects, grain. Mice. Bird eggs and young
Oriole (7½)	Head, neck and back black. Lower back and under parts, orange	Near houses, in elms. Orchards	Insects
Gold Finch (5¼)	Male, yellow with black cap and wings. Female, olive yellow, no cap	Woods and meadows	Seed of thistle, dandelion, etc.
English Sparrow (6¼)	Gray-brown. Breast black. Whitish beneath	City bird. Enemy to native birds. Resident	Grain, seeds. Insects
Song Sparrow (6¼)	Back gray-brown striped. Breast black spotted	Gardens and woods. Fine song. Resident	Weed seeds. Insects
Barn Swallow (7½)	Forehead and throat chestnut. Back, steel blue. Forked spotted tail	Meadows, near water. Barns	Insects
Yellow Warbler (5)	Greenish yellow above. Clear yellow below. Breast brown striped	Shade trees. Gardens and shrubbery	Insects

Name and size	Color	Habitat	Food
Cat Bird (9)	Head and tail black. Other parts dark gray	Woods and lawns. Often near water	Insects and wild fruits
Chickadee (5¼)	Head black. Back gray. White underneath	Woods, fields, and orchards. Resident	Insects and seeds
Robin (10)	Head black. Back slaty. Brownish red beneath	Gardens, lawns, and orchards	Earthworms, grubs, insects, fruits
Herring Gull (24)	Back grayish white. Head and under parts white	Streams, lakes, and sea shore	Fish, refuse. Scavengers
Screech Owl (9½)	Two color phases, brown and chestnut. Much mottled with light and dark. Large ear tufts	Nest in hollow trees. Nocturnal. Resident	Insects. Rodents
Bluebird (7)	Back blue. Breast chestnut. Female duller	Orchards and fields. Nest in holes	Insects. Wild fruits

One Portion Food Tables

The following tables are used by the permission of Professor Frank A. Rexford, from whose *One Portion Food Tables* they are taken. They furnish the easiest means of estimating whether one's diet is properly balanced.

Each item is calculated as being about the amount one would eat as one "helping" or "portion" as food is usually served.

FOODS PRIMARILY OF PLANT ORIGIN

Food as We Eat It	Of This the Body Can Use: Muscle Builder — Protein	For Heat and Energy — Fat	For Heat and Energy — Carbohydrates (Starch and Sugar)	This Portion can Yield to the Body in Energy and Heat Units
Beverages	Ounces	Ounces	Ounces	Calories
Cocoa	.11	.33	.19	123
Coffee (cream and sugar only)	.01	.17	.27	53
Bread				
Biscuit, soda	.19	.27	1.05	216.3
Bread, corn	.16	.09	.93	150.6
" graham	.18	.04	1.04	151.3
" wheat	.18	.03	1.07	153.1
" plain rolls	.19	.08	1.2	182.08
" and butter	.22	.48	1.18	275
Crackers, saltines	.11	.13	.69	125.3
" soda	.1	.09	.73	120.3
Toast, dry	.06	.008	.3	44.4
Cake				
Chocolate, layer	.14	.2	1.6	256.8
Cookies, molasses	.13	.16	1.32	209
Doughnuts	.12	.37	.93	218.8
Frosted	.12	.18	1.3	211.9
Fruit	.12	.22	1.28	220
Sponge	.09	.16	.9	168.3
Cereals				
Corn flakes	.07	.003	.59	77.6
Oatmeal	.13	.02	.49	76.5
Puffed rice	.04		.4	50.9
Rice	.11	.001	.96	124.72
Shredded wheat (2)	.21	.03	1.56	212.5
Fruit				
Apple, baked	.02	.02	.78	98.5
Bananas	.05	.02	.77	100.8
Olives, green	.01	.37	.15	116.3
Oranges	.04	.01	.58	75

FOODS PRIMARILY OF PLANT ORIGIN.—*Continued*

Food as We Eat It	Of This the Body Can Use			This Portion can Yield to the Body in Energy and Heat Units
	Muscle Builder	For Heat and Energy		
	Protein	Fat	Carbohydrates (Starch and Sugar)	
Miscellaneous	Ounces	Ounces	Ounces	Calories
Brown gravy	.03	.26	.07	81.2
Hash, beef	.26	.27	.32	114.3
Macaroni	.36	.02	2.00	286.2
Salad-dressing (French)		.74	.02	100.4
Nuts				
Almonds	.05	.14	.04	47.8
English walnuts	.08	.32	.08	103.4
Peanuts	.13	.19	.12	80.1
Pie				
Apple	.29	.31	1.44	282.8
Lemon	.14	.4	1.4	297.2
Mince	.65	.42	1.51	362
Pumpkin	.15	.15	1	177
Pudding				
Blanc-mange (chocolate)	.1	.3	.49	148.8
Custard	.16	.16	.35	102.4
Rice	.12	.28	.55	149.5
Tapioca	.11	.1	.92	146.3
Salad				
Egg mayonnaise	.26	.25	.02	100.1
Fruit	.04	.02	.52	70.4
Potato	.09	.22	.29	102.1
Tomato (with mayonnaise)	.06	.16	.15	67.6
Soup				
Bean	.38	.07	1	182.8
Cream of celery	.11	.34	.17	124.8
Consommé	.1		.02	16
Clam chowder	.09	.04	33	60
Tomato	.13	.12	.33	91.2
Vegetable (canned)	.13		.02	192.8

FOODS PRIMARILY OF PLANT ORIGIN.—*Continued*

Food as We Eat It	Of This the Body Can Use: Muscle Builder — Protein	For Heat and Energy — Fat	For Heat and Energy — Carbohydrates (Starch and Sugar)	This Portion can Yield to the Body in Energy and Heat Units
Sugars	Ounces	Ounces	Ounces	Calories
Candy, chocolate	.01	.01	.73	90
Chocolate, almonds	.06	.15	.95	160
Maple syrup			.89	103.9
Sugar (granulated or loaf)			.25	27
Vegetables				
Beans, baked	.31	.18	1.08	182
" kidney	.22	.65	.6	97.5
" string	.69	.61	.21	48.72
Beets	.05	.002	.15	26.1
Cabbage, boiled	.03	.09	.16	35.2
Celery	.01	.003	.04	5.5
Corn, canned	.08	.03	.52	74.25
Carrots	.04	.02	.35	49.2
Lettuce	.01		.03	7
Onions, creamed	.04	.15	.15	65.7
Peas, canned	.09	.09	.54	66.6
Potatoes,	.09	.06	1.26	173.4
" white, mashed	.09	.26	.68	100.4
" " baked	.1	.01	.26	98.1
Succotash	.11	.03	.56	78
Tomatoes, sliced	.04	.04	.18	26.8
" stewed	.08		.08	16.4

FOODS PRIMARILY OF ANIMAL ORIGIN.

FOOD AS WE EAT IT	OF THIS THE BODY CAN USE			This Portion can Yield to the Body in Energy and Heat Units
	Muscle Builder	For Heat and Energy		
	Protein	Fat	Carbohydrates (Starch and Sugar)	
Beef	Ounces	Ounces	Ounces	Calories
Corned	.21	.52		174.2
Dried	.26	.07		49.4
Round	.43	.29		125.2
Sirloin	.37	.36		137.1
Dairy Products				
Butter	.05	.43		112.5
Cheese, full cream	.26	.34	.02	122.4
Ice cream	.05	.1	.91	134.7
Milk, whole	.19	.24	.3	123.6
Oleomargarine		.4		110.2
Eggs				
Boiled (2)	.49	.45		179.1
Omelet	.48	.88	.03	296
Scrambled	.24	.17	.03	78.5
Fish				
Cod	.32	.02		101.6
Halibut, steak	.56	.16		105.9
Salmon, canned	.44	.24		114.1
Fowl				
Chicken (fricasseed)	.62	.4	.08	187
Turkey	.26	.26		104
Lamb				
Chops (broiled)	.43	.59		210
Leg	.67	.44		194.3
Mutton				
Leg	.62	.51		108

Foods Primarily of Animal Origin.—*Continued*

Food as We Eat It	Of This the Body Can Use			This Portion can Yield to the Body in Energy and Heat Units
	Muscle Builder	For Heat and Energy		
	Protein	Fat	Carbo-hydrates (Starch and Sugar)	
Pork	Ounces	Ounces	Ounces	Calories
Bacon	.1	.66		188.6
Chops	.47	.95		309
Ham, lean	.49	.55		203.2
Sandwiches				
Cheese	.41	.49	1.2	314.2
Egg	.4	.37	1.19	279.7
Ham	.33	.48	1.19	302.7
Sausages				
Country	.56	.8		278.1
Shell-fish				
Clams	.24	.02		32.2
Lobster	.32	.04		47.6
Oysters	.21	.04		36.4
Veal				
Cutlets	.7	.26		152
Leg	.65	.1		104
Liver	.56	.17		107.1

FIRST AID TREATMENT FOR EMERGENCIES

Bruises. Symptoms: Swelling; black and blue spot; pain. Treatment: Very cold or very hot water at once. Arnica or witch hazel. Raise injured part.

Sprain. Symptoms: Swelling at joint. Severe pain, increased by movement.

Treatment: Heat or cold for several hours. Absolute rest. Call doctor for severe sprain, especially of ankle.

Dislocation. Symptoms: Deformity of joint. Limited movement. Intense pain and swelling.

Treatment: Send for doctor. Do not try to reduce a dislocation except of jaw or finger. Get patient in easy position. Treat joint with hot or cold compresses.

Fracture (broken bone). Symptoms: Pain and tenderness. Deformity; loss of rigidity; grating of broken ends.

Treatment: Do not move broken parts. Send for doctor. Prevent movement by support on pillow or folded coat.

If patient *must* be moved, the injured limb should be well padded and "splints" bound alongside which will entirely prevent motion. Flat pieces of wood, canes, umbrellas, wire netting, heavy cardboard, rolled blankets, or clothing may be used for splints. Belts or handkerchiefs will hold them in place.

Ordinary wounds. If a wound does not bleed, aid bleeding by pinching. Do not handle cut surface, nor wash with water. Treat at once with diluted tincture of iodine. Cover with sterile dressing if possible. Adhesive plaster should not be used except to hold dressing in place.

Strong antiseptics, like bichloride of mercury or carbolic acid, destroy white corpuscles and should not be used.

Wounds with hemorrhage (bleeding). Symptoms: Blood flow from arteries comes in spurts, and the blood is bright red; that from veins comes in steady flow and is a little darker color.

Treatment: Send for doctor. Unless wound is on the head, keep head low and wound high; keep patient quiet. Try to check bleeding at once. For arterial bleeding apply pressure between wound and heart. For venous bleeding apply pressure on the wound itself.

Arterial bleeding from scalp wound may be checked by bandage around head just above the ears or by pressure on the temporal artery which can be felt in front of the ear, above joint of the jaw.

Other head wounds may be controlled by pressure on carotid arteries which are found by pressing backward, deeply into the neck along the muscle that extends behind the jaw to the base of the ear.

The subclavian artery which supplies the arm may be reached by pressing the thumb strongly into the hollow, behind and above the collar bone. The brachial artery of the upper arm can be compressed just behind the inner edge of the large arm muscle. For the hand, use pressure on the "pulse" and on the opposite side of the wrist.

The femoral artery supplying the leg can be compressed on the inside of the upper leg near the body. For the lower leg or lower arm, make a hard pad as large as an egg and bend the knee or elbow sharply over it.

A tourniquet, used to stop bleeding, consists of a pad and strap. The pad may be a smooth stone or other hard substance wrapped in the strap; the strap may be a towel, handkerchief, or tie. The pad is placed exactly over the artery, the strap loosely wound twice around the limb and pressure applied by twisting the outer loop with a stick.

Tourniquets can only be used to advantage on the brachial artery of the upper arm and on femoral artery of upper leg. Do not use one unless necessary and never leave in place continuously for over two hours; release as soon as bleeding will stop.

Important. Practice locating these arteries until you can find them quickly. Do not wait till the emergency comes. It is not easy even when you are not excited. If you really want to use this information, practice it in advance. Better still get your family doctor to help you or take the First Aid work in Scouts, Campfire Girls, or Red Cross courses.

Nose bleed. Harmless except when prolonged and severe.

Treatment: Loosen neck clothing; hang head over back of chair; apply cold to back of neck. Pressure on upper lip at base of nose. Plug nostril with cotton.

Burns. The best way to treat a burn is not to have one. Most fires and many burns result from carelessness, and could be avoided.

Clothing on fire can be smothered by wrapping from head downwards in rug or blanket. Do not run. Wet cloth over nose and crawling close to floor will help to breathe in smoke-filled rooms.

Treatment: Exclude air with paste of water and flour or starch. Vaseline or olive oil are good. Picric acid gauze or solution of Epsom salts are excellent dressings. Never dress a burn with absorbent cotton.

Deep burns or even blisters if extensive, should have a doctor's care.

Acids and alkalis cause burns similar to those caused by heat.

Treatment: Wash with water. Neutralize alkalis with vinegar or lemon juice. Neutralize acids with limewater. Use *dilute solutions* of limewater or vinegar respectively. For either acid or alkali in eyes *wash out* with much water.

Poisons. 1. Corrosive poisons: strong acids like sulphuric, nitric, or hydrochloric. Strong alkalis like lye, caustic soda, and lime.

a. Neutralize acid with magnesia, baking soda, soap, or wall plaster. Neutralize alkalis with vinegar, lemon, or orange juice.

b. Dilute and soothe with large doses of olive oil, salad oil, water, milk, flour and water, or raw eggs.

c. Stimulate with tea, coffee, smelling salts.

2. Irritant poisons: Paris green: bichloride of mercury, (antiseptic tablets); arsenic or phosphorous poisons for rats, etc.; plant poisons.

a. Produce vomiting *at once* by some means. Run finger down the throat; give much warm water and mustard or salt and water. Syrup of ipecac is good.

b. Dilute and soothe as for corrosives only use *no oils where phosphorus is concerned.*

c. Stimulate as for corrosives.

3. Nerve poisons: May be sleep producers like opium, morphine, laudanum, paregoric, soothing syrup.

a. Emetic.

b. Keep awake with strong coffee, walking.

c. Artificial respiration if unconscious.

May produce convulsions: strychnine, belladonna.

a. Emetic instantly.

b. Artificial respiration if breathing stops.

Artificial Respiration. The following directions for the Schaefer Method of resuscitation are taken from "Red Cross Life Saving Methods" by permission of the American National Red Cross, Washington, D. C., from whom much other valuable information may be had. This method may be used for stoppage of respiration from drowning, smoke or gas, electric shock, or certain poisons.

In application of artificial respiration, SAVE THE SECONDS AND YOU HAVE A BETTER CHANCE OF SAVING THE LIFE. Don't waste time carrying victim to a quiet spot. Work where he was taken from the water. Waste no time trying to get the harmless water out of the stomach. Turn subject face down and GO TO WORK *INSTANTLY*.

CAUTION. Often inexperienced or excited persons attempt to administer artificial respiration when there is no need for such treatment. It is required only when the victim is unable to breathe. If victim is brought from water unconscious, but breathing, he requires treatment for fainting or shock; that is, raising the feet, leaving the head low; applying stimulants such as aromatic spirits near nose; rubbing limbs and body toward heart to stimulate circulation.

Procedure. At place taken from water, gas, smoke, or electrical contact, lay the victim face downward on flat surface or with head slightly downhill. Turn his head to one side, extend both arms up beyond head and place one hand under face to protect his open mouth and nose from dirt. Kneel (straddling one or both knees) facing subject's head.

Place hands over lower ribs, one on each side of backbone and about four inches apart, thumbs and fingers together. If hands are in correct position, the little finger of each hand is over and following the line of lowest rib.

Move weight of body slowly downward and forward for about three seconds—don't slide. Keep arms straight. The shoulders should be behind the hands, so that pressure exerted is forward. Then snap the hands off, allowing ribs to expand quickly, filling lungs with air. Swing body slowly backward to upright position, thus relaxing muscles of back.

At the end of two seconds again place hands in position and apply pressure. This timing (three seconds pressure and two seconds release) uses five seconds for one complete respiration, assuring twelve respirations per minute. This is fast enough and will allow the operator to continue for some time without exhaustion.

To assist in properly timing these movements, repeat either silently or aloud during the period of pressure *"out goes the bad air."* Then *snap* off the hands and repeat during the period of release, *"in comes the good."*

Supplemental Treatment. As soon as helpers arrive, put them to work. Send for a doctor, for warm bottles or bricks, and for tea or coffee for stimulant. When you need rest, let one of your helpers take your place. One may clean the patient's mouth, stimulating reflexes by moving the tongue back and forth. Patient's clothing may be loosened, and his body and limbs rubbed toward the heart to stimulate circulation. Coverings and heated articles may be applied. (Be careful not to burn the patient.)

Aromatic spirits of ammonia may be placed near the patient's nose at frequent intervals. All of this treatment is helpful, but must not be allowed to interfere with, or interrupt for one second, the process of artificial respiration.

Don't give up! Persons who have been under water as long as thirty minutes have been resuscitated by this simple method. Even if no results are seen, the subject should not be abandoned until at least two hours' effort has been made to revive him.

When the subject begins to breathe and can swallow, give a teaspoonful of aromatic spirits of ammonia (NOT household ammonia), in half a glass of water. Hot water, tea, or coffee may be used as a stimulant if ammonia is not available.

Don't allow patient to walk or exert himself. After such an experience, a person requires medical attention and should be put to bed.

INDEX

Abalone, 531
Abdomen,
of grasshopper, 203
of butterflies, 213
of honey bee, 222
Abdominal cavity, 378
Abscission layer, 85, 99
Absorption, 421
root, 61
selective, 70
Acetic acid, 524
Acreolin, 592
Acrididæ (locust family), 184
"Adams' apple," 433
Adaptation, 37
Adenoids, 411, 432
Adrenal glands, 453
Aedes, mosquito, 237
Afferent fibres (sensory), 467
Agassiz Association, 339
Age of Metals, 372
Agramonte, Dr., 240
Aigrette, 341
Air pressure, 436
Alcohol, 524
effects on muscles, 386–388
ill effects of, 596–604
not a medicine, 603
Alcohol and circulation, 454, 455; — and digestion, 424, 425; — and excretion, 460; — and foods, 395; — and the nervous system, 474; — and respiration, 439
Algæ, 135
Alimentary canal, 409, 411
Alligators, 300
Almond oil, 515
American Association for the Advancement of Science, 570
American Ornithologists' Union, 339
Amœba, 159–162
Amphibia, 542
characteristics of, 266
comparison of appendages with man's, 270
Amylopsin, 420
Anemone, sea, 171
Animals,
general uses, 528
harmful kind, 528, 529
economic value of, 529
enemies to forests, 562
Animal husbandry, 553–555
Anise, 515
Anopheles, mosquito, 237
Antennæ,
of crayfish, 190
of grasshopper, 201
of butterflies, 212
Anterior (head end),
of crustacea, 190
of worm, 175
Anthers, 118
Anthrax, 146
Anthropology, 370
Antiseptic and aseptic surgery, 625, 626
Antiseptics, 151
Antitoxins, 146–150
Aphids, plant lice, 534
Appendix, 352, 360, 418
"Apple worm," 533
Aquarium, 608
Arachnida, 182, 532
Army and Navy hospital services, 585
Arrow-root starch, 516
Arsenate of lead, 537
Arteries, 272, 449
Arteriosclerosis, 599
Arthropods, 171, 172, 182, 199
characteristics, 182
classes, 182, 183

Arthropods,
  classifications, 183–186
Artificial respiration, 646, 647
Asparagus, 516
Assimilation, 8, 422
  in leaves, 110
Atropine, 524
Auditory canal, 479
Audubon, John James, 338, 632
Audubon Law, 339
Auricle, 447
Axon, 466

Bacteria, 135, 136, 549
  types, 142, 143
  reproduction, 142, 144
  occurrence, 144
  methods in study of, 144, 145
  useful forms, 145
  harmful, 146
  defences against, 146
  on the farm, 555
Bacteriology,
  methods used in study of, 144
  development of, 154
Bad Lands of Dakota, 557
Baking, of food, 402
Bark, structure, 86
Barley, 512
Barnacles, 532
"Baroque" pearls, 531
Bast,
  root, 59
  function of, 60, 61
  fibres and tubes (stem), 86, 87
"Bastard sawed," 564
Bayne-Blauvelt Law, 341
Bayne's, "Wild Bird Guests," 343
Beak, of bird, 310–312
Bee,
  honey, structure of, 220–223
  queen, 223, 224
  drones, 224, 225
  workers, 225
Beetle, Buffalo carpet, 535
Belladonna, 517
Benzoate of soda, 403
Beri-beri, 394
Berries, 519
Beverages, 594
Biffen, Prof. R. H., 550
"Big Trees" (Sequoia) of California, 92
Bignami, 241
Bile, 420
Bile sac, 420
Biology, definition, 3
  reasons for study of, 4
  sciences included in, 4
  economic, 38, 508
  civics, 501
  and agriculture, 547–555
  development of, 623–634
  history of, 621–634
Birds,
  characteristics, 303
  structure, 303–312
  habits of, 316–327
  value and protection, 330–339
  economic importance of, 330
  harm done by, 334
  economic value, 542, 543
  forests as homes for, 559
  some common, 636, 637
"Birds of America," by John James Audubon, 632
"Black bread," 512
Bladder, 457
Bladder, air, of fish, 258
Blade, leaf, 96
"Blanching," of plants, 112
"Blights," 146
Blood, 444–446
  changes in composition of, 446
Blood supply, 435
Blood vessels, 449–451
Board of Health, 586
Body, structure of human, 377–388
Body covering, of mammals, 346
Bone,
  composition of, 379
  structure of, 379, 383
  functions of, 383
Bordeaux mixture, 537
Borers, 534
Bradley, Warden, 341

Brain,
of fish, 258
of frog, 274
structure, 462
Branching,
due to leaf arrangement, 78
due to bud development, 78, 79
forked, 79
indefinite, 79
Breathing,
organs of, 432
rate of, 436, 437
air changes in, 437
Breathing movements, 431, 435
Breeding of plants, 550–552
Bright's disease, 460
British Millers' Association, 550
Bronchi and air cells, 433, 434
"Brood comb," 225
Brubacher, Dr., quoted, 600
Bruises, 642
Buckwheat, 512
Bud, structure, 82, 83
Buffalo carpet beetle, 535
Bugs, croton, 536
Burbank, Luther, 631, 632
Bureau of Biological Survey, 342
Bureau of Fisheries, 342
Burns, 644
Butterflies, 212–220
compared with moths, 216
metamorphosis of, 216

Cabbage worm, 535
Cactus, spineless, 631
Calcium, 17
Calcium compounds, 390
"Calorie," 396
Calyx, 117
Cambium, 59, 91
root, 69
stem, 86–89
Camera, the living, 483
Camphor, 516
Capillaries, 451
Carapace, 188, 189, 194
Caraway, 515
Carbohydrates, 27, 391
Carbon, 15
Carbon bisulphide, 537
Carbon circle, 610, 611
Carbon dioxide, 15, 24, 547
Carnivora (flesh eaters), 350
Carnivorous, 297
Carotids, 272
Carrel, Dr., 502, 626
Carrier pigeons, 331
Carrol, Dr., 240
Cartilage, 248
Casein, 417
Castor oil, 515
Caterpillar, tent, 533
Cattle, Texas fever, 165
Caudal (fin), tail of fish, 255
Celery, 515
Cells, 32, 623
specialization of animal, 169, 170
Cellulose, 391
Cephalopods, 531
Cephalothorax (head thorax), 188
Cereals,
grains, 510
kinds of, 511
Cerebellum, 464
of bird, 312
of fish, 257
Cerebrum,
of frog, 274
of bird, 312
of man, 463, 464
Chameleon, 299
Character, 473
Charcoal, 524
Chemical changes, 22
Chestnut blight, 138, 571
Chewing, 414
Chickens, value of, 334
Chitin, 201
Chlorophyll, 100
composition of, 102, 103
property of, 106, 107
Chocolate, 515
Cholera, 146, 233
Choroid, 481
Chromatin, 32
Chrysalis, 214
Chyme, 418
Cigarettes, 592

Cilia, 433
of paramecium, 162
Cinnamon bark, 516
"Circles of nature," 109, 610
Circulation, 8, 621
and alcohol, 454
need for, 443
development of, 443
of birds, 309
of blood, 431
of earthworm, 175
of fish, 256
of frog, 273
Cirrhosis of the liver, 425
Citrus canker, 583
Citrus fruits, 519
Civic biology, 501
Clams, 530, 531
Climate, effect of forests on, 559
Clinics, free, 586
Clinton, De Witt, 569
Cloaca, 275
Clothes' moths, 536
Coal, 522, 560
Cobra, 295
Coca, 515
Cocaine, 515, 605
Cochlea, 479
Cockroaches, 536
Cocoa, 514
Cocoa butter, 515
Cocoa oil, 515
Coconut, 515
Coconut fibre, 522
Cocoon, 215
Codlin moth, 533
Cod-liver oil, 542
Cœlenterates, 171, 530
Coffee, 514, 594
Coleoptera, 200
Coloration, protective, of animals and insects, 216–220
Comb, of honey bee, 225
Compound berries, 519
Compounds, 21
definition, 10
conditions of existence, 23
mineral, 24
inorganic, 24
Compounds,
organic, 26
Conjugation, of paramecium, 162, 163
Conservation of health, 584
Conservation of wild life, 576–579
Convolutions, 463
Cooking, functions of food, 401, 402
"Cooties," 536
Copperhead, 294
Corals, 530
Coral polyps, 171
Coral snake, 295
Cork, 523
Corn, 90, 91, 511
Corn borers, 535
Corn oil, 515
Cornea, 481
Corolla, 118
Corpuscles, white, 146, 148
of blood, 445
Cortex,
root, 59
stem, 86, 87
function of, 60
Cotton, 520
Cotton boll weevil, 535
Cotton-seed oil, 515
Cottony maple scale, 534
Cotyledons, 41
"Cowrie," 531
Cows, breeds of, 555
Crabs, 532
"soft shell," 195
Crane, 310
Cranial cavity, 377
Cranium, of fish, 258
Crayfish, 188, 532
example of crustacea, 188–196
Cretinism, 453
Crocodiles, 289, 300
Crop pests, 535
Crop protection, 581–584
Crops rotation of, 550
Crossbill, 312
Croton bugs, 536
Crude turpentine, 524
Crustacea, 182, 532
characteristics, 188

"Cud," 349
Culex, mosquito, 237
Culture medium, 144
Cuticle, leaf, 100
"Cuttle bone," 531
Cuttle fish, 531
Cyst, 177
Cytoplasm, 32

"Daddy-long-legs, 532
Darwin, Charles, 626, 627
his "Origin of Species by Natural Selection," 364
chief factors to account for development of new species from common ancestry, 365
Davenport, 368
"Deaf adder," 294
Deafness, 480
Deliquescent, 79
Dendrites, 466
Departments of Agriculture, National and State, 580
Department of Interior, 342, 578
Dermis, 458
Dextrine, 516
Diabetes, 453
Diaphragm, 435
Dicot, type of stem, 84, 85
Dicotyledonous stem structure, 85
Diet,
need of mixed, 398, 399
right and wrong, 400, 401
Digestion, 8, 409
of bird, 308
Digestive processes, demonstration of, 422–424
Digestive system,
of earthworm, 175
of fish, 255
of frog, 271
Diphtheria, 146
Diptera (two-winged), 200, 231
Diseases, eye, 146
foods and, 405
prevention of, 504
victories over, 625
Disinfectants, 152
Dislocation, 643
Distillation products, 524, 560
Dogwood, spare the, 573
"Domestic" animals, 544
Domesticated animals and plants, 361
Dorsal, 248
Dover Cliffs, in England, 529
"Dragon," 300
Drainage, control of, 509
Drugs, 524
narcotic, 605
Drum membrane, 478
Dry farming, 548
Duck, 310
Duckbill, 347
Ducts, stem, 87
Duct bundles, leaf veins, 96
Ductless glands, 452–454
Dutcher, William, 338
Dyestuffs, 523, 524
Dysentery, 233
(amœbic), 165

Eagles, 310
Ears,
of frog, 269
structure of human, 479
care of, 480
Earthworms, 174, 175
external features, 175
digestive system, 175
circulatory system, 175
excretory and nervous systems, 176
locomotion, 176
food, 176
economic value, 176, 177
Echinoderm, 251, 530
"Edible birds' nests," 321
Edwards, Jonathan, 630
Efferent fibres (motor), 467
Eggs, use, 323
Ehrlich, Paul, 625
Elements, definition, 11
condition of existence, 23, 614
Elephant, 347
Elliptical sac, 258
Embryo, definition, 40, 123

Embryological resemblances, 360
Endosperm, 41, 42, 123
Energy, 20
  sources of, 615
Environment, factors of, 37
Enzyme ptyalin, 416
Epidermis,
  root, 59
  function of, 60
  stem, 86, 87
  upper of leaf, 100
  lower of leaf, 101
  human, 458
Epiglottis, 411
Erosion, 559
Erysipelas, 146
"Essential organs," stamens and pistil, 122
Eustachian tubes, 269
Evolution,
  the idea of, 359
  evidences of, 359–363
  method of, 364–369
  things it does not teach, 368
  of life functions, 617–619
Excretion, 8
  organs of, 457
  and alcohol, 460
Excretory system, of earthworm, 176
Exercise and rest, 489
Exo-skeleton,
  of crayfish, 188
  of grasshopper, 201
Expiration, 436
Extensors, 383
Eyes,
  of fish, 253
  of frog, 269
  of bird, 312
  structure of human, 481, 482
  protection of, 483
  defects of, 483–485

Factory conditions, 504, 505
"Family resemblances," 363
Farm, bacteria on the, 555
Farm Bulletin, No. 609, and No. 621, 343
Farming, dry, 548
Fatigue, 470
Fatigue toxins, 471
Fats, 28, 391
"Feathering," 305
Feathers, of bird, 303–306
Federal departments, 585
Federal Food and Drug Law, 404
Federal Migratory Bird Treaty Act, 340
Federal protection, of wild life, 580
Federal Tariff Bill of 1913, 340
Feeding, of birds, 316–319
Feet, of birds, 310
Fehling test, 28
Femur-rubrum (red-legged), 184
Ferns, 135
Fertilization,
  plant, 123
  bird, 331
Fertilizers, 549
Fever, typhoid, 146
  Texas cattle, 165
  yellow, 165, 236
  scarlet, 165
  yellow, mosquito only carrier of, 240
Fibre plants, 520–522
Fibrinogen, 445
Filaments, 118
Finches, 312
Fins, of fish, 255
Fire, enemy of forests, 561
Fish,
  structure, 251–259
  reproduction, 259
  value of, 541, 542
  conservation of, 579
  hatcheries, 579, 580
Fisher, Dr. Irving, 395, 488, 597
Fission, 161
Fixation, root, 61
Flax, 521
Flax oil, 515
Flexner, 626
Flexors, 383
Flight, of birds, 323, 324
Flowers,
  function, 117

Flowers,
  structure, 117, 118
  as food, 519
  protection of wild, 575, 576
Flukes, 530
Fly,
  typhoid (common), 231, 232
  reproduction, 232–235
  danger from, 232, 233
  tsetse, 233
  control, 235
  ichneumon and tachina, 536
  lacewing, 537
Focus, human eye, 483
Food,
  preservation of, 153, 403
  of some common birds, 318
  definition, 389
  functions of inorganic, 390
  functions of organic, 390–392
  vitamines, 392–395
  lipsoid, 395
  measurement of value of, 396, 397
  proportions, 397, 398
  digestibility of and cost of, 399
  special, 402, 403
  adulteration, 404
  and disease, 405
  control, 502, 503
  tables of portions, 638–642
Forest rangers, 563
Forest Service, 342
Forestry, as a vocation, 566, 567
Forestry schools, 563
Forests, value of, 557–561
  enemies of, 561
  protection of, 562, 563
  conservation of, 569, 570
  causes of destruction of, 570–572
  means of protection for, 573–576
Formalin, 552
Fracture (broken bone), 643
Frog,
  construction, 267–275
  development of, 281–283
  reproduction, 281–283
Fruits,
  types of, 127, 128, 129
  structure, 127
Fruits,
  functions of, 129
  economic importance of, 132, 133
  as food, 519
"Fuel foods," 392
Fuels, 522, 560
Function, 35
  common to plants and animals, 37
  evolution of life, 617–619
Fungi (parasite), 135, 136
  examples, mushrooms, 137
  other examples, rusts, smuts, mildew, 137
  molds, 138
Fungicides, 538
Fungus enemies of forests, 561
Funk, Casimir, 392

Gall, 420
Galton, Sir Francis, 630, 631
Gamboge, 524
Game, forests as home for, 559
Game birds, 330
Ganglia, 466
  in insects, 206
Gastric fluid, 417, 418
"Generalized order," of animals, 351
Genus, 183
Geological evidence, 361
Geotropism,
  the response of plant parts to gravitation, 69
  negative, 71, 72
Germ transmission, some means of, 243
Germs, disease, 163
Germination, 50
  conditions for, 55
Gila Monster, 299
"Gill bailer," of crayfish, 190
Gills, of fish, 253, 254
Giraffe, 347
Girdling, 89, 90
Glands, 414, 415
  lymph, 148
Glottis, of frog, 274
Glucose, 28
Glue, 542
Gluten, 402

Glycogen, 420
Goiter, 453
Gorgas, Colonel W. C., 239
Gourd fruits, 519
Grafting, 88
Grains, cereal, 510, 511
Grain smuts, 583
"Grain," of timber, 563, 564
Grape sugar, test for, 28
Grasshopper, 200
  structure, 201–208
Grassi, 241
Grippe and colds, 146
Guano, 331
Gullet, 417
Gums (drugs), 524
Gypsy moth, 535

Habit,
  parasitic, of plants and animals, 180
  formation, 472
  selection, 472–474
Hæmoglobin, 445
  of the blood, 437
Harlequin snake, 295
Hawks, 310
Healing a wound, 446
Health, 488
  conservation, 584
  private means of conservation, 587, 588
Hearing, 478
  how we hear, 480
Heart, 447
  action of, 447–449
Heart and sap-wood, 565
Heat energy, 12
Heliotropism, 98
Hemiptera, 200
Hemp, 522
Henderson, W. C., 332
Hereditary, disease germs, 154
Heron, 310
Hessian fly, 581
Hilum, 40
Hollow spheres of cells, 169
Homologous organs, 361
"Honey," 226
Honey bee, 220–228
"Honeydew," 534
Hookworms, 178
Hops, 519
Hormones, 453
Hornaday, William T., quoted, 290, 294
"Horned toad," 299
"Horsehair snakes," 178
Household pests, 535–537
Housing conditions, 504, 505
Hummers, 310
Humus, 548
Hunter, Mr. Arthur, 602
Hurty, Dr. J. N., 603
Huxley, 368
Hybrids, 121
Hydra, 171
Hydrocyanic, 537
Hydrogen, 15, 614
Hydrotopism, the response of plant parts to water, 69, 70, 72
Hygiene, definition, 5
  of muscles, 488, 489
  mental, 490
  of digestion, 492
  of teeth, 493
  of respiration, 493, 494
  of eyes, 495
  of bathing, 495, 496
  of feet, 496, 497
  of nerves, 498
Hyla, 285
Hymenoptera (membrane winged), 220
Hypocotyl, 42
Hypopharynx, 202

Iceland moss, 520
Ichneumon flies, 536
Iguanas, 299
Immunity,
  natural, 147
  acquired, 148
Impulses,
  motor in animals, 206
  nerve, 468
Incubation, 323
Indigo, 523

Industries, of a bee colony, 227
Inflammation, of wound, 446
Inheritance, 366
Inhibition, 472
Inoculation, 144
Inorganic substances, 3
Insect destruction,
  by birds, 331, 332
  insecta, 182, 184, 199
  classification, 200
Insects,
  larval forms, 227
  economic relations of, 532, 533
  methods of control, 536, 537
  enemies of forests, 561
Insecticides, 537, 538
Inspiration, 435
Interdependence, of plants and animals, 170, 171
Interrelations, 610
Intestinal glands, 419, 420
Intestines, 418–420, 458
Involuntary muscles, 383
Iris, of eye, 481
Iron, 17
Iron compounds, 390
Irritability, 477
Isinglass, 542
Ivory, 544

Japanese beetle, 582
Jaws, 248
  of snakes, 290
Jellyfish, 171
Jenner, Dr. Edward, 623
Johnson, Walter, 387
Jute, 521

Keen, Major W. W., M. D., 368
"Keeping cool," 438
Kernel, 41
Kidneys, 457
King, A. F. A., 241
Kissinger, 240
Knots, in lumber, 565
Koch, Robert, 625

Labium, 201, 213
  of honey bee, 221
Labrum, 201, 212, 213
Lacteals, 420
"Lady-bird" beetle, 536
Lamarck, 364
Larva, of butterfly, 214
Larynx, 433
Law of conservation of matter and energy, 608
Lazear, Dr., 240
Leather, 544
Leaves,
  functions, 96
  structure, 96, 97
  forms, 97
  adaptations for exposure, 97
  modifications of, 98
  fall of, 98, 99
  minute structure of, 99, 100
  other functions, 109, 110
  as factories, 110
  as food, 516–518
Legal protection, for forests, 562
Legs, of frog, 269–271
Legume, 128, 512
Lens, of eye, 481
Lenticels, 85
Lepidoptera (scale winged), 200, 212
Leprosy, 146
Lice, 536
Lichens, 135
Life, 12
  functions, 617–619
Limbs, of mammals, 346
Linseed oil, 515
Lipoid, 395
Lister, Sir Joseph, 625
Liver, 420, 458
Lizard, 285, 289, 299
Lobsters, 532
Lockjaw (tetanus), 146
Locomotion,
  of earthworm, 176
  of crayfish, 193
  of snake, 292
Locust, 200
Logwood, 524
Loon, 310
Lumbering, careful, 562
Lumbering, careless, 561

Lungs, 431, 434, 458
  air capacity, 435
  of frog, 274
Lymph, 422
Lymph circulation, 451, 452

Mace, 515
Macey, 598
Maggots, 232
Magnesium compounds, 390
Malaga grapes, 584
Malaria, 236, 241
  parasite, 241
  see Protozoa, 165
Mammals,
  characteristics of, 345
  food, 543
  clothing, 543
  various products, 544
  transportation, 544
  pets, 544, 545
Man, 351
  development of, 359–363, 370–374
  enemy to forests, 561
Mandibles,
  of butterflies, 212, 213
  of crayfish, 190
  of grasshopper, 201
  of honey bee, 200, 201
Manila fibre, 522
Manson, Dr., 241
Mantis, 208
Maple sugar, 560
Marsh Island, Louisiana, 342
Marsupials, 347, 348
Matter, 20
  law of conservation of, 23
  states of, 23
Maxillæ,
  of butterflies, 213
  of crayfish, 190
  of grasshopper, 201
  of honey bee, 221
McIlhenny, Edward, 342
McLeod, Warden, 341
McNary-Clarke Act, 574
Medicines, patent, 505, 506
Mediterranean fruit fly, 584
Medulla, of fish, 258
Melanoplus (black armored), 184
Melon fly, 584
Mendel, Gregor, 627–631
Mendel's Law of Inheritance, 630
Menhaden, 541, 542
Mental development, affected by tobacco, 593
Mesothoracic, wings of grasshopper, 202
Metamorphosis,
  of amphibia, 266
  of butterfly, 216
  of frog, 283
  of grasshopper, 207, 208
Metathoracic, wings of grasshopper, 203
Metazoans, 167
  forms of, 171, 172
Metchnikoff, 626
Methanol, 604
Methods of attracting birds, 342, 343
Mexican fruit fly, 584
Meylan, Dr., 593
Microbes, 163
Micropyle, 40, 123
Migration, of birds, 324–327
Milt (spermatic fluid) of fish, 259
Mimicry, color protection, 219, 220
Mineral compounds, 24, 390
Mineral salts, necessity for, 390, 401
Mites, 532
Mixtures, 21
Moccasin, water, 294
Molds, 138, 139
Molluscs, 171, 530, 531
Monocot, type of stems, 84, 85
Monocotyledonous stem, 90, 91
Moran, 240
Mosquito, 236
  disease transmission, 236
  reproduction, 236, 237
  control, 238–240
  only carrier of yellow fever, 240
  carrier of malaria, 241–243
Mosses, 135
"Mother-of-pearl," 531
Moths, 212–220
  compared with butterflies, 216

Moths,
gypsy, 535
tussock, 534
clothes, 536
Motion, 9
Motor fibres, 467, 468
Motor impulses, in animals, **206**
Moulting,
of birds, 306
of crayfish, 195
of grasshoppers, 206, 207
Mouth, 411
of fish, 253
of frog, 268
of grasshopper, 201
Mud puppies, 285
Muscles, 383, 385
of birds, 308
of frog, 271
effect of alcohol on, **386**
Mushrooms, 137
Mustard, 515
Mycelium, 139
Myriapods, 182

Names, scientific, 185
Narcotics, 395
effect on cell life, 604
Nasal cavities, of fish, 253
Naval stores, 560
Nectar, 119
Nerves, 466, 467
Nervous system, 462
and alcohol, 474
of arthropods, 205
of birds, 312
of earthworm, 176
of fish, 257
of frog, 274
processes centered in, 470
Nests, of birds, 319–321
Neurons, 466
New Stone Age, 372
Newts, 267, 285
Nicotine, 522, 591
Nictitating membrane, 269
Nitrogen, 14
circle, 611, 615
fixation, 509

Node, 97
Nostrils, of frog, 269
Nucleolus, 32
Nucleus, 32, 160
Nurses, visiting, 586, **587**
Nutmeg, 515
Nutrients (food stuffs), 389
Nutrition, 8, 422
Nuts, 513

Oats, 511
Octopus, 531
Oils, 515
Old Stone Age, 372
Olfactory lobes, of fish, 257
Operculum, 253
Opium, 519, 605
Opsonins, 148
Optic lobes, of fish, 257
Organic substances, 3
likeness of, 9
difference from inorganic, 9
Organs, 35
analogous, 176
homologous, 191
sense, of bird, 312
of grasshopper, 201
systems of, in frog, 275, 276
Oriental fruit worm, 582
Orthoptera (straight winged), **184**, 200
Osmosis, 67, 68
successive, 70
variations in, 71
to demonstrate, 72, 73, **74**
and life, 615–617
Ovary, in flowers, 118
Over-production, 365
Ovipositors, 203
Ovules, 118
structure, 122, 123
Ovum, 322
Owls, 310
Oxidation, 12, 622
in plant tissues, 110
and life, 614, 615
Oxide, 12
Oxidize, 615
Oxygen, 12, 113

Oxygen,
circle, 611
soluble in water, 194
supply, 509
Oysters, 531

Palate, 411
Palisade layer, of leaf, 100
Palpi, 478
Palpus, 201
Pancreas, 420, 453
Pancreatic fluid, 420
Paper, 560
materials, 522
Paramecium, 162, 168
structure, 162
reproduction, 162, 163
Parasites, plant, 136
animals, 177–181
Paris green, 537
Parkes, Dr., 387
Parrots, 311
Pasteur, Louis, 154, 624
Patent medicines, 505, 506
Peanut oil, 515
Pearl oysters, 531
Pearl tapioca, 516
Peat, 522
Peepers, 285
Pelican Island Reservation, 341
Pepsin, 417
Peptones, 417
Perching, of birds, 309, 310
Perspiration, 458
Pests,
fruit tree, 533–535
shade tree, 534, 535
crop, 535
household, 535–537
Petals, 118
Petiole, leaf, 97
Phosphates, 17, 390
Phosphorus, 16, 614
Photosynthesis, process of starch-making in leaves, 106
materials used in, 107
energy for, 107, 108
compared with respiration, 111, 112
Physical changes, 22
Pigeons, carrier, 331
"Pilot snake," 294
Pinchot, Gifford, 570
Pine blister rust, 138
Pistil, 118
"Pit vipers," 294
Pith, 87, 88, 91
Pituitary gland, 453
Plants,
general uses of, 508
fibre, 520–522
lice (aphids), 534
breeding, 550–552
protection, 552
Plasma, 445
Pleurisy, 434
Pleurococcus, 135
Plover, 310
Plum, pitless, 632
"Plumcot," 631
Plumule, 42
Pneumonia, 146
Poisons,
corrosive, 645
irritant, 645
nerve, 645
Pollen, 118
protection of, 122
structure, 122
Pollination, 118, 119
cross, 119
insect, 119
wind, 120
prevention of self-pollination, 120, 121
artificial, 121
aided by butterflies, 216
Polycotyledonous stems, 92
Polyps, coral, 171
Pomes, 128, 519
Poppy, ten-inch, 632
Portal (vein), 273
Posterior, extremity of worm, 175
Posture, 497
results of erect, 352
Potash, 516
Potassium, 17, 614
Potato "bug," 535

Potato, Burbank, 631
Potato wart, 138, 583
Pouched animals, 347
Priestly, 622
Primates, 350
Primitive man, 372
"Primus Berry," 631
Proboscis, elephant's trunk, 347
Processes, 466
Products, forest, 559–561
Propagation, root, 61
Propolis, bee glue, 227
Proteins, 26, 390
Prothorax, of grasshopper, 202
Protoplasm, 31, 159, 623
Protozoa, 159, 529
  parasitic, 163, 165
Protozoan, 167
  malaria parasite, 241
Pruning, 90
Pseudo-neuroptera, 200
Ptomaine (poisoning), 146
Puff-balls, 135
Pulmonary, 272
Pulse, 450
Pupa, of butterfly, 214
Pupæ, of fly, 232
Pylorus, 418
Pyramids, 529

Quarantine, 153
"Quarantine examinations," 585
Quarter grain, of timber, 564
"Quartered oak," 564
Quebracho, South American, 523
Quinine, 524

Rachis, 304, 305
Rattlesnake, 294
Red Cross, 587
Reed, Major, 240
Reflex action, 466, 468, 469
Reflex arc, 469
Reforestation, 562
Remedies, to combat destructive insects, 583, 584
Rennin, 417
Reproduction, 9
  of amœba, 161, 162
  of birds, 321–323
Reproduction,
  of butterflies, 214–216
  of fish, 259
  of fly, 232
  of frog, 275, 281–283
  of grasshopper, 206, 207
  of honey bee, 223–225
  of mosquito, 236, 237
Reptiles, 289–300, 542
Reservations,
  for birds, 341
Respiration, 8
  artificial, 646, 647
  of bird, 308
  of crustacea, 193
  of frog, 274
  of grasshopper, 204
  of leaf, 96
  of man, 431
  in plant tissues, 110
Rest, 470
Resuscitation, Schaefer Method, 646, 677
Retina, 481
Rheumatism, 460
Rib muscles, 435, 436
Rice, 511
Rickets, 393
"Rift sawed," 564
Rind, stem, 91
Rings, annual, *see* Wood fibers
Rockefeller Foundation, 342
Rockefeller Institute for Medical Research, 504
Rodents (gnawers), 348
Rogers, Dr. O. H., 602
Roosevelt, Theodore, 570
Roots, 58
  adaptations of root form, 61, 62
  aerial, aquatic, fibrous, fleshy, soil, tap, 62
  brace, climbing, parasitic, propagation, 63
  as food, 515, 516
  functions of, as a whole, 61
  hairs, 68, 69
  kinds of, 61
  normal adventitious, 62
  pressure, 70, 71

Rosin, 524
Ross, Dr., 241
Rotation of crops, 550
Roux, 154, 625
Rubber, 523
Rye, 512

Sago starch, 516
Salamanders, 267, 285
Saliva, 416
Salivary glands, 415
Salmon, life history of, 260–262
Sanitation, definition, 5, 487, 503
San José scale insect, 582
Saprophytes, 136
Scale insects, 534
Scales, fish, 252
Scallops, 530
Scars,
  leaf, 85
  flower-bud, fruit, 86
  bud-scale, 86
Schaefer method of resuscitation, 646, 647
Schick test, 151
Sciences included in Biology, 4
Scientific names, 185
Sclerotic coat, of eye, 481
Scorpions, 532
Scurvy, 394
Sea anemone, 171
Sea cucumbers, 530
Seal, 251
"Seasoning," of timber, 565
Seed, 40
  examples of structure, 43
  function, 50
  dispersal of, 130, 131
  by wind, animal, water, and mechanical, 132
  origin of parts, 123, 124
Semicircular canals of the ear, 479
Sensation, in animals, 206
Senses, of frog, 274
Sensitivity, 9
Sensory fibres, 467, 468
Sepals, 117
"Sepia," 531
Serum, 445
Setæ, 175
Sewage disposal, 503, 504
Shade tree pests, 534, 535
Shasta daisy, 632
"Shell-fish," 251
Shrinkage, of timber, 565
Sight, 480, 481
"Silver-fish," 251
Simple berries, 519
Skeleton, 378, 379
Skin, 458
  structure of, 458
  functions of, 458–460
Sleep, 471, 472
Sleeping sickness, 165, 233
Slugs, 531
Smallpox, 148
Smell, 478
Snails, 531
Snakes, 289
  false ideas about, 289, 290
  poisonous, 293–295
  treatment for bites, 295, 296
Snapping turtle, 297
Snipe, 310
Sodium, 17
"Soft-shell" crabs, 195
Soil formation, 547, 548
  composition, 549
  maintaining, 549
  benefit to forests, 559
Solar plexus, 470
"Song box," 309
Sources of energy, 615
Sparrows, 312
Special adaptations of mammals 346
Special foods, 402, 403
Species, 183
Spencer, Herbert, 366, 627
Spices, 515
Spiders, 532
Spinal bulb, 464–466
Spinal column, 248
Spinal cord, 466
Spineless cactus, 631
Spiracles, 203
Spirogyra, pond scum, 135

Sponges, 529
Spongy layer, of leaf, 101
Spontaneous generation, 621, 622
Spore-bearing plants, 135
classification of, 135
Spore plants, as food, 520
Sprain, 642
Spruce gum, 560
Squash bug, 535
Squid, 531
Stamens, 118
Standard Bird Law, 339
Starches, 391
Starch-making in leaves, *see* Photosynthesis
"Star-fish," 251, 530
State departments, 585 586
Steapsin, 420
Stems, functions of, 77, 78
shortened, 79
creeping, 80
climbing, 80, 81
fleshy, 81
structure 84, 86
arrangement of tissues, 84
as food, 516
Stigma, 118
Stimuli, 172
"Sting," of honey bee, 222
Stomach, 417
Stomates, 102
Stone fruit, 127, 519
Storage, root, 61
Struggle for existence, 365
Strychnine, 515
Sugar, maple, 560
Sugars, 391
Sulphur, 16, 614
oxide of, 16
"Sulphur showers," 120
Surgery, antiseptic and aseptic, 625, 626
Survival of the fittest, 366
Swimmerets, 190
Sympathetic system, 469, 470
Syphilis, 165

Table beverages, 594, 595
Tachina fly, 536
Tadpole, 274, 281
"Talons," 310
Tanning materials, 523, 560
Tapeworm, 177
Tarsi, 202
of common (typhoid) fly, 232
Taste, 478
Tea, 594
Teeth, 412–414
of mammals, 346
Tegumen, 40, 123
Telson, 190
Tent caterpillar, 533
Terrapin, 296
Terrarium, 609
Testa, 40, 123
Tetanus, 151
Thalessa, long tailed, 537
Thoracic appendages, of crayfish, 190
Thoracic cavity, 377, 378
Thorax, of butterflies, 213
of grasshopper, 202
of honey bee, 222
Thyroid gland, 453
Ticks, 532
Timber, 522, 523
products, 559, 560
structure, 563–566
Tissues, 35
function of stem, 86, 87
Toads, 267, 284
tree, 285
"Toad-stool," 137
Tobacco, ill effects of, 591–594
Tongue, 411, 412
of frog, 268
of snake, 292
Tonsils, 411
Tooth decay, 146
Tortoise, box turtle, 297
Touch, 477
Tourniquet, 644
Toxin, 148
"Toxin-antitoxin" treatment, 150
Tracheæ, 183, 352, 432, 433
of frog, 274
of grasshopper, 204
Trachoma, 165

Transpiration, 110, 115
  leaf, 96
Trees, street, 566
  surgery of, 566
"Tree-toad," 267, 285
Trichina, 177, 178
Trichinosis, 178
Trunk, of fish, 255
Trypsin, 420
Tsetse fly, 233
Tubercles, 145
Tuberculosis, 146, 233, 587
Turgescence, 67
Turtles, 289, 296–299, 542
Tussock moth, 534
Typhoid, 233
Tympanic membrane, 269, 479
Tympanum, 478
Typhoid fly, 231
  vaccination, 149

Ungulates (hoofed animals), 348
U. S. Biological Survey, 578
U. S. Bureau of Entomology, 571
U. S. Bureau of Fisheries, 579
Uric acid, 460
Urine, 457

Vaccination, 148, 149, 623
  typhoid, 149
Vacuoles, 32, 160
Valves, of heart, 447
Vane, 304
Variation of individuals, 366
Vascular bundles, 91
Vaso-motor nerves, 598
Veins, 451
  leaf, 97
  portal, 273
Ventilation, 437–439, 494
Ventral, 248
Ventricle, 447
Vertebræ, 248
Vertebrates, 171, 172
  development of, 247
  classes and characteristics, 248
Villi, 419
"Vinegar eel," 178
Visiting nurses, 586, 587
Vitamines, 26, 392–395
Vocal organs, 433
Voluntary muscles, 383
Volvox, 169
Von Behring, 155, 625
Von Bunge, Dr., quoted, 597
Von Mohl, 623

Walking, 385, 386
Wallace, Alfred Russel, 366, 627
Walnut, thin-shelled, 632
"Wampum," 531
Ward, Charles, 342
Warping, of timber, 565
Waste product, of leaves, 108, 109
Water, necessity of, for plants, 66
  control of supply, 557
Wax, ear, 480
  of honey bee, 225
Weather conditions, enemy to forests, 562
Web membrane, of frog, 270
"Weeds," 509
Weeks-McLean Law of 1913, 340
Weevil, cotton boll, 535
Whale, 251, 347
Wheat, 511
Wheat rust, 138, 583
Whip-poor-wills, 310
White, Dr. Andrew D., quoted, 593
White matter, 460
White pine blister rust, 570
"White plague," 587
Whooping cough, 146
"Wild Bird Guests," by Baynes, 343
Wild Flower Preservation Society, 576
Wild life, conservation of, 576–579
Wiley, Dr. Harvey, 603
Williams, Dr. Henry Smith, 502
Wing, of bird, 306
Witch hazel, 516
Wood, fibers, 86, 87, 88
  hard and soft, 565
  root, 59
  stem, 86

Wood alcohol, 524, 604
Woodhead, Dr., quoted, 599
Worms, 530
  cabbage, 535
  parasitic, hook, tape, trichina, 177, 178
  true, 171
Wound, healing a, 446
  ordinary, 643
Wound,
  with hemorrhage (bleeding), 643, 644
"Wrigglers," 237

Yeast plants, 139, 140
Yellow fever, 165, 236
  mosquito only carrier, 240

Xerophthalmia, 393